UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola d'Enginyeria de Barcelona Est

DEGREE THESIS

Degree in Energy Engineering

GREEN ENERGY WATER WELL

Report and Annexes

Co-Autor: Darcel Aurel Yoya Tchaptchet

Co-Autor: Sergi Ortega Ruiz

Director: Hermio Martínez-García

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Abstract

This Energy Engineering final project consists of the realization of an international cooperation project between Catalonia and Cameroon to implement borehole running with clean energy in order to supply the 2,000 inhabitants of Banekane with drinking water. The use of photovoltaic solar energy has been considered to electrically feed a submersible pump that will be responsible for sucking water from a water borehole for later consumption.

Prior to the conception of this work, it was investigated and verified that the problem and the possible solution were adapted to local needs of Banekane to justify the realization of this project. Next, the technical, economic and ecological feasibility of its implementation was studied and subsequently effort was put into place to materialize the idea.

This project will study the natural features (groundwater and solar resources) of the work field where the project will be implemented so that the proposed solution is truly efficient and will last over the years. The technical calculations necessary for the sizing of installation will be carried out and all the phases that have led to its completion and launching will be described. Moreover, the involvement of the sponsors and the fundraising process carried out will be detailed. Given that the project has a social aspect and that the use of renewable energy is promoted, an observation of the social and ecological impact it will have on the locality will be made.

Furthermore, the document will include the economic report, the plans and the annexes where the technical data sheets and the technical reports made by the companies contracted in Cameroon will be accessible.

Keywords: International cooperation, drinking water, photovoltaic solar energy, Cameroon

Resumen

Este trabajo de fin de grado de Ingeniería de la Energía consiste en la realización de un proyecto de cooperación internacional entre Catalunya y Camerún para implementar un pozo funcional a base de energía limpia a fin de abastecer con agua potable a los 2.000 habitantes del pueblo de Banekane. Se ha contemplado la aplicación de energía solar fotovoltaica para alimentar eléctricamente una bomba sumergible que se encargará de succionar agua de un pozo para su posterior consumo.

Previo a la concepción de este trabajo, se investigó y se comprobó que la problemática y la posible solución se adecuaran con las necesidades locales para justificar la realización de este proyecto. A continuación, se estudió la viabilidad técnica, económica y ecológica de su implementación y posteriormente se trabajó para materializar la idea.

En este proyecto tiene se estudiará las características naturales (aguas subterráneas y recursos solares) del campo de trabajo donde se implementará el proyecto para que la solución propuesta sea verdaderamente eficiente y dure a lo largo de los años. Se realizarán los cálculos técnicos necesarios para el dimensionado de la instalación y se describirán todas las fases que han conducido a su finalización y puesta en marcha. Igualmente, se detallará la implicación de los patrocinadores y el proceso de recaudación de fondos llevado a cabo. Dado que el proyecto tiene un aspecto social y que además se promueve el uso de las energías renovables, se hará una observación de la repercusión social y ecológica que tendrá en la localidad.

Asimismo, en el documento se adjuntará, la memoria económica, los planos y los anexos donde se podrán consultar las fichas técnicas y los informes técnicos realizados por las empresas contratadas en Camerún.

Palabras clave: Cooperación internacional, agua potable, energía solar fotovoltaica, Camerún

Resum

Aquest treball de fi de grau d'Enginyeria de l'Energia consisteix en la realització d'un projecte de cooperació internacional entre Catalunya i Camerun per a implementar un pou funcional a base d'energia neta a fi de proveir amb aigua potable als 2.000 habitants del poble de Banekane. S'ha contemplat l'aplicació d'energia solar fotovoltaica per a alimentar elèctricament una bomba submergible que s'encarregarà de succionar aigua d'un pou per al seu posterior consum.

Previ a la concepció d'aquest treball, es va investigar i es va comprovar que la problemàtica i la possible solució s'adeqüessin amb les necessitats locals per a justificar la realització d'aquest projecte. A continuació, es va estudiar la viabilitat tècnica, econòmica i ecològica de la seva implementació i posteriorment es va treballar per a materialitzar la idea.

En aquest projecte s' estudiarà les característiques naturals (aigües subterrànies i recursos solars) del camp de treball on s'implementarà el projecte perquè la solució proposada sigui veritablement eficient i duri al llarg dels anys.. Es realitzaran els càlculs tècnics necessaris per al dimensionament de la instal·lació i es descriuran totes les fases que han conduït a la seva finalització i posada en marxa. Igualment, es detallarà la implicació dels patrocinadors i el procés de recaptació de fons dut a terme. Atès que el projecte té un aspecte social i que a més es promou l'ús de les energies renovables, es farà una observació de la repercussió social i ecològica que tindrà en la localitat.

Així mateix, en el document s'adjuntarà, la memòria econòmica, els plans i els annexos on es podran consultar les fitxes tècniques i els informes tècnics realitzats per les empreses contractades a Camerun.

Paraules clau: Cooperació internacional, aigua potable, energia solar fotovoltaica, Camerun

Résumé

Ce projet final du cursus de génie énergétique consiste en la réalisation d'un projet de coopération internationale entre la Catalogne et le Cameroun visant à mettre en place un forage fonctionnel a partir d'une énergie propre afin de fournir de l'eau potable aux 2.000 habitants de la ville de Banekane. L'application de l'énergie solaire photovoltaïque a été envisagée pour alimenter électriquement une pompe immergée qui sera responsable de d'aspirer l'eau du forage pour sa consommation.

Avant la conception de ce travail, il a été étudié et vérifié que le problème et la solution éventuelle soient adaptés aux besoins locaux pour justifier la réalisation de ce projet. Ensuite, la faisabilité technique, économique et écologique de sa mise en œuvre a été étudiée et un effort a ensuite été mis en place pour concrétiser l'idée.

Ce projet étudiera les caractéristiques naturelles (eaux souterraines et solaires) du champ de travail sur lequel le projet sera mis en œuvre afin que la solution proposée soit réellement efficace et dure au fil des ans. Les calculs techniques nécessaires au dimensionnement de l'installation seront effectués et toutes les phases ayant conduit à son achèvement et à sa mise en service seront décrites. De même, l'implication des sponsors et le processus de collecte de fonds mis en place seront détaillés. Étant donné que le projet a un aspect social et que l'utilisation des énergies renouvelables est encouragée, une observation de l'impact social et écologique qu'il aura sur la localité sera faite.

De même, le document comprendra le rapport économique, les plans et les annexes où les fiches techniques et les rapports techniques des sociétés sous contrat au Cameroun pourront être consulter.

Mots-clés : coopération internationale, eau potable, énergie solaire photovoltaïque, Cameroun.

Nə̀ məmtə (Abstract in medumba langue)

Sə̂n fǎ' nə̀ miɑgtə laŋ ŋwà'nì mbwôgvə lî, sə a yi'tə ɑ̂ nǔm kǔmshunngɔ̀ nətɛ̌d Pɑ̀nyɑ bô Kamerun nɑ, kə ndiag ɑ̂ nə̀ ghʉ̀ ndʉ bə̀n nca'bɑhɑ (2000) bò bə̂ Nənkɑn nɑ ghʉ̌ ntsə nəlɑnə, ncʉɑ̂tə njǎm tà' ngʉ̂' nəlɑnə. Bò a' cʉɑtə̀ ɑ̂ njǎm mbwôgvə̀ bô nyàm kɑ nsôŋ ntsə nə̀ nu ncǔ lǒŋntsə bo nsi coŋ nsi lɑ.

Bo bə mǎ' fì' sə̂n fǎ' lî, mbwôgmbwə nsiaŋtə, mbɛn ndɔtə à bə zə̀ à kuâg ɑ̂ kuà' nǔ zə̀ a cwɛ̌d nja bɑ̆ la' lɑ, mbɛn nzwi'tə à bə zə̀ bìn i cô nyɑ̀m nɑ. Ndô bwə, ndɔtə à bə zə̀ bò kû'ni nə̀ fà' i à kə̀ ghʉ̀dnǐ nǔm bǎg ngɑ̂mvə̀, ngɑ̂mfu', mbɑ̀ ngɑ̂mdʉ̌'yog lɑ, kɑ mbə bam mə̀sɔ nkə nsɔ̂.

Nǔm nə̀ ghʉ̌ sə̂n fǎ' li jʉ mbɛn ngobtə, bò à' totə kɑ ndɛ̂n lɛ̌n ntsə à bə̂ bǎm ca' lɑ, ndɛ̂n njòŋ nyǎm nǔm ntɑ lɑ. Bò à' tata nǔm nə̀ ghʉ̌ mfì' tsinə, mbâgtə njǒŋ ndâŋ fà' fa, nəto'tə nǔm màd nə̀ kûd yi, nə̀ ghʉ̌ à to' nə̀ zìnə, màd bo soŋtə bɑ̆ təntom nɑ, màd bo kʉ̂mtə̀ nkɑ̂b yi lɑ, mbɑ̀ à bâtə yǒg bɑ̆ la' mbɑ̀ yub dʉ̌'yog lɑ.

Bò à' bə miɑ̀gtə̌, ntswîtə tsə̀mô' cûfà' mbɑ̂ cɔ̀fǎ' ngɑ̂mfù', bɑ səvə, bɑ mfəngɑ̆mvə̀, cu cən nɑ tsə bɑ kǔmshun kǔ'ni nə lò' mfâ' yi lɑ.

Kǒ' ndɛ̂ncu: kǔmshûnngɔ̀, ntsə nəlɑnə, ngʉ̂'nyàm mbwôgvə̀, Kamerun

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1. Preface

1.1. Origin of the project

Applying the knowledge and skills acquired during this Energy Engineering course, in particular those acquired within the lectures of the subject of Renewable Energies instructed by Dr. Herminio García Martinez, has been one of the main goals of this project.

Darcel, has always had the will to return to his country (Cameroon) to apply the knowledge obtained abroad and to contribute to the development of his homeland. Knowing the difficulties due to the lack of drinking water at Banekane (his father's and grand-father's village) and talking to family members and other inhabitants living in Banekane, the goal to put into fruition this project was set. In order to give a better ascertain the objectives of this project, it has also been possible reach out university professors (Université des Montagnes) and members of the public administrations in Banekane.

Sergi, has lived for 10 years in Colombia with his parents at ONG Provalores residence. He has been able to witness several cases of orphan or abandoned little boys and girls that later on within the years were able to improve their educative, economic and social state. This experience has inspired him to work and contribute to the improvement of the living situation of those in disadvantage.

The overall goal is to fight against endemic diseases (diarrhea, cholera, hepatitis A, typhoidal fever…) resulting from the usage of non-potable water. These illnesses mostly affect the younger population (0 to 13 years). Likewise, this project also aims to involve and give an opportunity to young students in Cameroun, since they acknowledge they have a lot of theorical knowledge but very few to none means to put them into practice. Them taking part in this project involving an application of solar photovoltaic energy will serve as a way increase their technical abilities and also to promote the usage of this technology which could be used for future others projects. This project will also aim to give them responsibilities for their capabilities to be taken more seriously and for them to show their importance in the development of the community. Young women have to deal with this problem at a higher degree, for this reason, it will be asked that at least 50 % of the students involved should be women. The goal of this decision is to try to encourage and boost their confidence for them to involve themselves in similar projects in the future.

The advantages of a solar water borehole system are the great amount of water that can be extracted and supplied for a low inversion cost. Furthermore, water extracted from a borehole in a rural area is potable and of good quality in most of cases. This is due to its natural filtration through the different levels of ground till it reaches the aquifer. The presence of groundwater and the propitious point to drill will be verified through a series of tests (hydrogeophysical study). Due to the overall geographical situation of Cameroon as a hole and precisely solar radiation at the location considered (data obtained from PVGIS database), it is more than verified the availability of abundant solar resources. This project has as one of its primary goals the promotion and usage of this renewable, clean and sustainable source of energy.

A water borehole operating with solar photovoltaic energy can impact positively on several humanitarian and social issues. This is the reason why Banekane public school, the university students in Cameroon (UdM) and those in Spain (UPC), professors at UPC, ONG Provalores and others have considered putting into fruition this project.

1.2. Motivation

Firstly, it's not necessary to mention the usefulness of water in our lives as a primary need to survive, to have a healthy life or to realize our daily activities. Drinking water is limited resource on this planet and there are locations where a proper access is not assured. Supplying drinking water to this area will help in reducing the proliferation of endemic illnesses like cholera, diarrhoea, typhoidal fever… This will contribute to the improvement of the general health of the population.

Secondly, it's important to take into account that the children of the village are those in charge of travelling long distances to fetch drinking water to support their parents and younger siblings. Implanting this project will be a great help in avoiding these children to walk through long and unsafe paths. The time they spend fetching water will be put to a better use at school learning or playing, as kids they are.

Thirdly, this project offers an opportunity to both UPC and UdM students to acquire practical abilities. This will make both parties gain experience in the realisation of projects involving renewable technologies and help them become better professionals in the future occupations. In Cameroon, students mostly get theoretical knowledge, but due to lack of investment and opportunities they are not able to put those concepts into practice.

Lastly, we will like to foment and encourage the participation of women in tasks leading to the local improvement.

1.3. Prior requirement

The prior requirements for the execution of this project are primarily the financing of the project and the knowledge acquired within the subjects of our engineering course. Some of these subjects are: Energy Resources, Static Energy Converters, Renewable Energy…

Another important prerequisite for the implementation of this project is the collaboration of some local entities in Cameroon such as the city hall of the municipality of Bangangté and the local chief of the village.

2. Introduction

The production of energy from renewable sources to meet our needs is gaining more importance in this world where the effects of the acceleration of climate change due to human activity become to be taken more seriously globally. Several economically and technically effective technological applications of renewable energy are discovered and developed to reduce the emission of toxic waste or greenhouse gases to the atmosphere.

2.1. Objectives and reach of the project

The general goal of this project is to improve the life and the welfare of the population of Bangangté. The specific goal is to obtain an improvement of the welfare and health of the population in Banekane.

This project of the NGO Provalores proposed by university students of UPC, aims to design and implement a pumping system to extract potable water in a rural area in Cameroon (Banekane). The electrical power needed to power the water pump will be provided by solar photovoltaic energy.

The aim of this practical project is to provide proper water to the 2000 inhabitants of Banekane. The water pulled out from the borehole will be drinking water. It will be used to drink, cook, face washing and dishwashing but NOT for other domestic uses such as bathing, laundry, irrigation, water for livestock...

Furthermore, a cascading program of formation will be implemented starting from the university students of l’Université des Montagnes. Then, they will transmit their knowledge to the rest of the population. The information to provide will be primarily the importance of potable water to prevent endemic illnesses.

Eventually, a water management committee will be established in order to ensure the proper use of potable water and to assure the longevity of the installation.

3. Cameroon

3.1. The country's description

Cameroon sometimes referred to as the ''hinge'' of Africa, Africa in miniature, because of its geological and cultural diversity. More than two hundred ethnic and linguistic groups live in Cameroon, and the number of inhabitants rises to 24,053,727.

3.1.1. Geographic description

It has borders Chad, the north, the Central African Republic in the east, Nigeria to the west, Gabon, Equatorial Guinea and the democratic republic of Congo to the South. It has an area of 590 km2 and has 10 regions: The Adamaoua, the Center, the East, the Extreme North, the Coast, the North, the Northwest, the Southwest and the South.

These regions are divided in 54 departments composed of 360 districts. Every region is under the authority of a governor who is the representative of the state in that region.

The western parts of Cameroon are dominated by high plateaus and mountains such as mount Cameroon (4100 m), mount Manengouba (2250 m), mount Kupe (2070 m), mount Bamboutos (2740 m), mount Nkogam (2263 m), mount Oku (2119 m). The far north of the country is a semi-desert broadening into the vast Maroua Plain, with game reserves and mineral deposits. In the centre, there are pastures and the vegetation is mostly savanna at the Adamaoua plateau which elevations can reach as high as 2650 m. In the South, tropical forests and swamps abound.

Cameroon mostly has two main types of climates, Equatorial and tropical.

The equatorial extends itself over all the south Cameroonian plateau. It is characterized by abundant rains (more than 1500 mm per year). it is also extended over the high plateau of the west and mount Cameroon region. A long rainy season that last approximately 9 months and a short dry season.

The tropical climate reigns over the north, Adamaoua and the Benue. Where there is a more extended dry season, a lower precipitation rate and high temperatures.

3.1.2. Historical, political and economic situation

The Portuguese sailors reached the Cameroonian coast in 1472, but the German Emperor implemented a colonial regime in 1884. After the First World War, the territory was spited into French and British. In 1961 the south of British Cameroon decided to unify itself to French Cameroon, meanwhile the north preferred to join itself to Nigeria.

In the 80's and the 90's the crisis affected the economy due to the complex international economic climate, dryness, the fall of oil's prices, political corruption and bad management. Cameroon asked for foreign financial help, reduced funds for education, government management, public health and it also privatised companies.

Nearly 70% of the population is engaged in subsistence agriculture. The dependence in exporting agricultural products (coffee, tobacco, cocoa…) makes Cameroon a vulnerable country to the variation of its prices. Cameroon possesses a great reserve of mineral resources, but they are widely exploited. The exploitation of oil has felt since the 80's due to the second world oil crisis, but it continues to be a substantial sector that has got a strong impact in the economy of the country.

In 2017, its gross domestic product (GDP) was of 30.928 M€ and its GDP per capita was of 1.288€. 50,6% of the population lives with less than 1,76€ per day and 17,1% with less than 0,88€ per day. The birth rate is about 4,86 children per woman, the life expectance is approximately 55 years. Nearly 40% of the population is less than 15 years old and 70% is less than 30. In the southern areas of the country almost all children of the age of primary education attend school. Nevertheless, at the most isolated north, the school absence is high.

President Paul Biya has been in power for 35 years now and was recently re-elected for another seven-year term in the country after a hectic scrutiny that took place on October 7, 2018, and challenged by the majority of the public opinion and the opposition parties that followed the Constitutional Court whose president was appointed by Paul Biya, in order to establish clarifications on the conditions of the voting procedure and notably on the count of the votes. The principal party of opposition, the MRC (Movement for the rebirth of Cameroon) and its leader, Pr. Maurice Kamto demanded for light to be shed on these issues, highlighting corruption and fraud in the country's electoral processes.

After all these events, the tension was palpable but it quickly fell after the appeals to calm, requested by the international community.

With the organization of the CAN (African Nations Cup) 2019 withdrawn from Cameroon, the central government is still subject to many criticisms by Cameroonians who are increasingly sceptical about the effectiveness of the government appointed by Paul Biya, who said that this seven-year period will be that of "great opportunities" after having named the precedent "seven-year period of the great achievements", which has ended on a negative balance at all levels. In this new year 2019, the time is in the preparation of the legislative elections that will take place in November 2019, in order to renew the 180 members of the National Assembly of Cameroon. The forecasts point to a crushing victory of the party in power, the CPDM (Cameroon People's Democratic Movement), in spite of the MRC's calls to all its supporters to register massively on the electoral lists to decrease the opportunities of victory of the CPDM.

With regard to the situation of young Cameroonian people, they are increasingly interested in the political issues of the country because they have a thirst to see a change due to the fact that there is an increase in graduates who encounter difficulties in finding jobs. In the African countries, the problem of youth employment is a real disaster, and in Cameroon this problem is taking worrying proportions. In spite of the efforts of the State and its attempts to provide answers, the unemployment of the young people persists, this is due to corruption and the bad management of the resources of the country. Today, young people feel abandoned and more often turn to organized crime from hence the problem of growing insecurity. These sometimes prefer to opt for clandestine immigration in order to achieve better living conditions because Europe is considered there as an "El Dorado".

3.2. Banekane

From time immemorial, obtaining good water in sufficient quantity without having to travel a long distance has always been a top priority for man, because of the utility of this resource in most sectors of human activity. For this, various actions are undertaken with the aim not only to ensure access to water for the population, but above all to work to ensure that this water is drinkable. It is then at the level of these two aspects that lies the real hydraulic problem in Cameroon. This problem therefore falls in terms of water quality, as well as the inexistence or the lack of a water supply and distribution system, or a strategy to make drinking water accessible to the population.

However, the problem of drinking water supply is perceived in unequal terms from one locality to another within the State of Cameroon. For our part, we have chosen to study the drinking water supply system of the BANEKANE village in order to identify the various water concerns of the population, to propose a drinking water supply project to BANEKANE and make relevant recommendations to ensure sustainable water security for the people of this community.

3.2.1. Geographic, historical and economic situation of Banekane

The village BANEKANE belongs to the commune of BANGANGTE in the region of western Cameroon. It is located in the North of its chief town.

The area is located on a hillside plunging south. The relief here is a glacis with variable slopes. The difference in level between the site and the bottom of the nearest valley is of the order of 20 m.

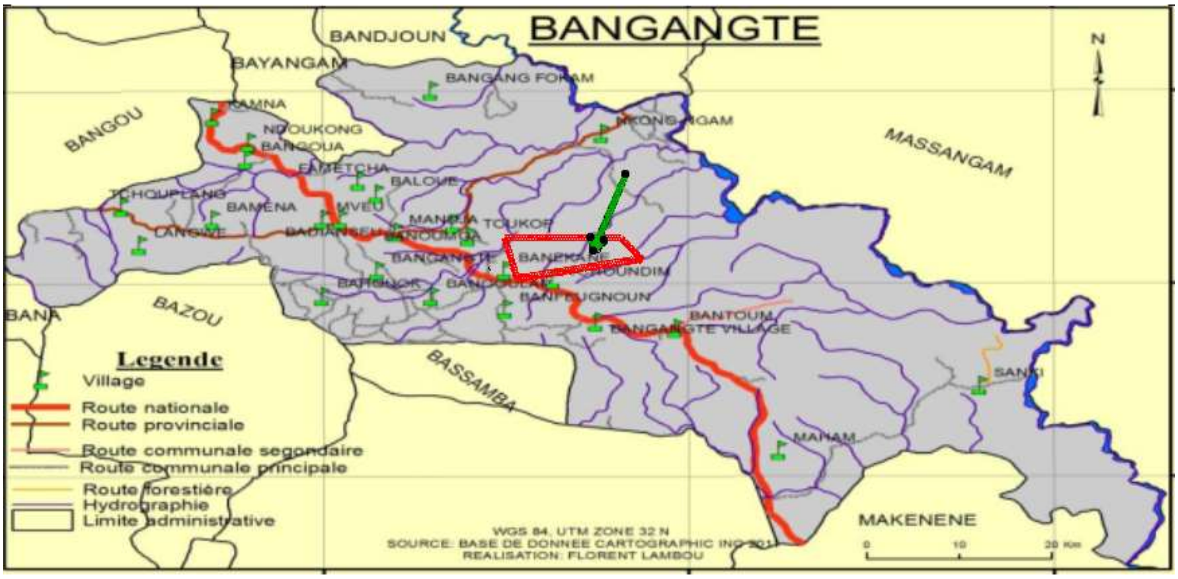

Figure 3.1: Bangangté's road map. Source: Bangangté's town hall

The climate in this area is the same as that of BANGANGTE commune is influenced by the topographic nature of the area, conferring a climate of altitude. The average annual temperature is between 14 °C and 28 °C. However, high temperatures are observed in lowland forests and plains. Generally, temperatures range from hot and humid in low-lying areas, to cold and dry in high altitude areas. Temperature inversions occur in valleys and depressions. Much of this area is marked by two major seasons: a generally shorter dry season, from mid-November to mid-March, and a rainy season from mid-March to mid-November. However, there are small variations in the date of beginning and end of the rains. The average annual precipitation is between 1400 and 2500 mm but unequally distributed in the 8 months of the year.

The Bamilékés are a union of several semi-Bantu ethnic groups, many are concentrated in the region of the West of the country, to the West of the Noun River and to the Southeast of the Bamboutos mountains, the Mungo region of the Provinces Litoral, South-West, and Center, with the capital in Bafoussam. The Medumba language is one of the 11 languages of the Bamiléke people. It is the spoken and written language especially in the department of Ndé (Bangangté, Bangoulap, Bakong, Bahouc, Bagnoun and Tonga). The name Medumba is of Egyptian origin, it comes from *Medu Mba*, a language of Ancient Egypt meaning *Divine Language*. The population comes from several migratory waves from Ancient Egypt. Medumba is mainly an art, a forum grouping the residents of the department of Ndé with the aim of promoting and defending cultural and artistic values, thus sensitizing the people to the need to value the multi-dimensional heritage of Ndé

In villages such as Banekane, there are many few schools for primary or secondary education and these are built of temporary materials. In many schools in Bangangté's villages there is a lack of rooms, materials and teachers, and these few are poorly paid.

The commercial activities of the inhabitants of Bangangté are mainly cattle ranch, agriculture, the sale in markets and the intercity transport.

Banekane village belongs to the commune of BANGANGTE in the region of western Cameroon. It is located in the North of its chief town. Banekane has about 2000 inhabitants. This population engage in two main economic activities:

- Livestock (cattle, dromedaries, goats, etc.)
- Agriculture: cereals mainly grown in the rainy season and off-season, through irrigation, allow the production of vegetables grown in the swamps (tomatoes, onions ...).

Residents buy their supplies from vendors, but most of them consume water from the backwaters, nearby sources, and UdM's borehole water, which are not of good quality.

3.3. Water issues

In the Ndé Departament, located in the region of West Cameroon, precisely the locality of Banekane where the project will be established. The problem to obtain drinking water is a serious issue because the water network managed by the national company of water distribution "CDE" (Cameroun Des Eaux) is not reliable and is practically non-existent in some areas forcing people to travel long distances to obtain water for household needs.

Figure 3.2: water supply point (1)

Figure 3.3: water supply point (2)

The locality of Banekane is currently fed by SINEC (5% of the population benefits from this water). There are also two water boreholes equipped with human-operated pumps, one located at Université des Montagnes (about 3.5 km from the center of Banekane, fig. 3.5) and the other one at the Protestant Church of Cameroon (1 km from center of Banekane) and wells (mostly traditional). The field study reveals that 15% of this population benefits from quality water and the 85% remaining consumes water from rivers and other accessible but bad quality waterbodies.

It is therefore essential to improve the drinking water supply system of this locality, to modernize it and to improve access to drinking water for the population.

Figure 3 4: water supply point (3)

Figure 3.5: supply point from the water borehole close to UdM. Source: Own picture

After questioning some people in Banekane about the need for water and most of them do not have a source of water in their homes and get water from a seller and most of them use water from sources. Some local people interviewed told they boiled and let rest for few days before drinking the water collected from waterbodies like those shown in fig. 3.2, fig. 3.3 fig. 3.3. Most others do not even boil the water and drink it only after letting it settle.

A field trip done by some of our mates from l'Université des Montagnes enabled us to identify the different sources of drinking water in the Banekane area. The results are grouped in the following table:

Table 3.1:census result

Designation	**Number**	**Observation**
SINEC		- poor water quality, regular water cutoff - only 20% of the population benefits from this water and for most cases this water is used by private individuals
Water borehole	Two	- the first is that of l'Université des Montagnes, located at a faraway (very difficult for the population to get there) from the population of Banekane and its use is restricted

		- that of the evangelical church of Cameroon. Its usage is restricted only providing water to a primary school which is located nearby
Traditional well	About 10	- 40% are abandoned because of poor maintenance and because they dry up in the dry season. - 20% are not completely. Their drillings were interrupted because difficult to penetrate rocky levels were found. - 15% are located in zones far away from the areas of concentration of the populations of Banekane. - The rest are mostly for private use
River	three	- Most of the population drinks this water - The same water is used for domestic tasks (clean up, laundry, shower….) - This brownish water is used without being boiled and is of very poor quality and is likely to cause illness in the population of Banekane

The realization of this project will help in reducing health issues due to non-potable water and relieve children who must travel a long distance to get water so they will have more time to dedicate to education.

4. Theorical framework

This section will explain all technological developments used in the industrial field and produced by different companies with reference to water pumping. Given the location of the project, the state of the art will be studied both globally and locally, the importance of the study and use of the technologies used in Cameroon will allow proper maintenance or repair of the installation.

4.1. Energy sources for water pumping

The energy consumption required to drive water from the subsoil to the consumer can come from different sources.

The first and oldest is the human or animal force, in prehistoric China manual perforations were already excavated from the year 6,000-7,000 BC according to texts of the Western Zhou dynasty, likewise, there is a well with wooden cladding in Schletz in Austria dating in the year 5,200 a. C. This basic technology has a low cost, provides small flow rates and poor water quality since it is used in shallow manual drilling. It is usually used in third world countries, mainly in rural areas.

Figure 4.1: Manual water well in Banekane, Cameroun Source: Own Picture

Secondly, we find the use of fossil fuel. It has attractive advantages over other sources of energy such as low investment cost, high power or no need for a storage system. However, the problems generated by monthly costs related to the purchase of fuel in addition to the increase in pollution and the imminent decrease in fossil resources worldwide generate the need to reduce the use of this technology. It is usually used when large quantities of water need to be extracted and high power is required since the other alternatives are not able to supply these values.

One of the best alternatives for those solar pumping installations that require moderately high-power values is wind energy, with this the electric consumption of the pump is supplied. Another alternative is the generation of mechanical energy with a piston or centrifugal pump although it gives little flow and reaches maximum depths of only 25m. In both cases the maintenance costs are low.

Another source of highly used energy is photovoltaic energy, facilities of this style usually have a useful life of 20-25 years if quality material is purchased and proper maintenance tasks are done. On the contrary, the power is low and an oversize of 10-20% is needed to raise the water when the pump is stopped, some projects use a diesel generator instead of this oversized although in practice it is not usually profitable.

On the other hand, the initial investment is high although it can be amortized in a few years of operation, especially in countries with large amounts of irradiation. In Cameroon specifically, photovoltaic energy is used frequently, it is usually installed in height for greater security.

Figure 4.2: Photovoltaics panels Douala, Cameroun Source: Own Picture

The main drawback of the use of renewable energy such as wind or solar energy for pumping water is the need to use storage systems to meet the demand when such a resource is available.

Finally, there is the grid's electrical power being the energy resource of any kind used in the different countries: Solar, wind, nuclear ... Specifically, the most interesting for this project is hydroelectric power since it is the most used in Cameroon for distribution. The main problem of using Cameroon's power grid to boost the pump is that in the dry season there is a shortage of hydroelectric resources and a high demand for water consumption, mainly affecting rural areas such as Banekane, in addition, the infrastructure has a low reliability In large cities such as Douala or Yaoundé there are several pumps connected to the electricity grid since it is more reliable than in the exteriors although they still need the use of tanks as a storage system to face the power outages.

The different energy sources can be combined with each other to complement, decrease the storage system or have more power if you do not want to oversize as it could be in the case of photovoltaics. To a large extent it will depend on the flow, the manometric height and the location of the project.

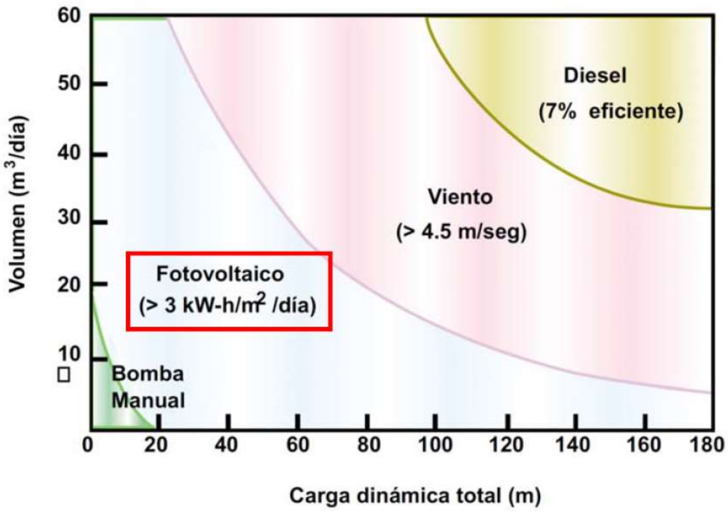

Figure 4.3: Power of the different energy sources for water pumping applications (course ENRE, EEBE-UPC)

4.2. Groundwater detection system

To detect the presence of groundwater you have to use a number of methods and conduct some previous studies of the land.

First of all you should do a geological study of the area, see what type of material is the most abundant, since aquifers can have both detrital soil (sandstones, gravels ...), these would be the type of porous soil, as in soils of carbonated material (limestone, dolomites ...), these would be those of karst soil type; This first study in the detection is important because depending on what type of soil we are drilling operations will be more or less expensive.

Then you will have to carry out a study of the land relief. Depending on the relief it will be more or less complicated to find an aquifer and reach it, since the steeper the terrain, the more complicated it will be to use depending on what kind of machinery. Something similar happens with vegetation, the more vegetation the less likely we are to have an aquifer; for example, in a free porous aquifer (it is said of that an aquifer that is in detrital sediment and that only the lower sediment layer is impermeable to this one) if there is a lot of vegetation this will cause a screen effect to occur and will not let infiltrate as much water as it should, thus hindering the extraction of water.

Once these previous studies have been carried out and the possibility of an aquifer is determined, various methods can be carried out to find the aquifer.

The first, based on the pseudoscience called radiesthesia, is the dowser method; according to the dowser the method consists of detecting the electromagnetic radiation of the water by means of a pendulum or two branches in the form of "V". Although scientifically there is nothing proven this technique has been used for several centuries and is even used by European companies.

With this case we will not focus on pseudoscientific methods, but we will give more importance to scientifically proven methods through geophysics.

The “Remote Thermal Tomography” (TRT) is a geophysical research method which allows the identification of geological structures, underground water resources and geothermal resources in large areas. This method is based on the endogenous heat flux of the earth which allows to determine the thermal range of the soil. To find out if there is an aquifer in the desired study area, the thermal difference between water and soil is used since, as it is well known, water takes longer to cool than the earth's surface; thanks to this fact we can determine the area in which the aquifer is located. The strengths of this method are that it covers large territories, allows to reach great depths and in comparison, to other methods does not have such high costs; The biggest limitation is that the research scale is 1: 100,000 and that there is little availability of good quality images.

Another method to find signs of aquifers is the profiles of electrical tomography (ERT). This method itself is useful because it is based on measuring the variations of the physical parameter of the electrical resistivity of the subsoil materials and provides information on the layers that exhibit different electrical behaviour. The more porous materials will have a lower resistivity to the compact materials, which will have a higher electrical resistivity; in the case of layers that are not lithological, such as an accumulation of water, its resistivity will be almost nil. Once the survey information is obtained, it must be correlated with the geological information available in the area. Among the possible methods, this would be the most complete, since it gives information on the soil in which the aquifer is located and also reports the presence of water; The negative part of this method is that it is not effective on large surfaces unless the necessary amount of cable and electrodes is needed and the geography is not very steep because it is difficult to move all the necessary material (batteries, cables, dipoles , electrodes ...) and much time and effort is lost in transportation and preparation.

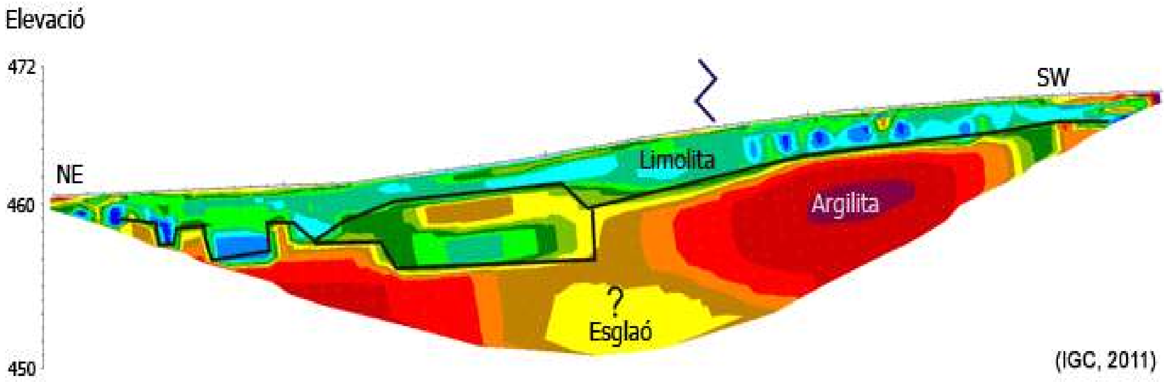

Figure 4.4: Electrical resistivity model of the subsoil on a tomography Source: Instituto Cartográfico y Geológico de Cataluña

To finish the most useful method to find water is the "Proton Magnetic Resonance" (RMP), this method is the most useful because it is the only geophysical method that allows not only to detect water directly, but also allows to know the distribution of the water content and the depth of the aquifer. This method is based on the fact that hydrogen nuclei located in a magnetic field such as Earth's, have magnetic moments that, in equilibrium, are aligned in the direction of this natural magnetic field; once a disturbing magnetic field is emitted at a specific frequency (Larmor frequency) the equilibrium is modified and a precession of these moments is induced around the direction of the natural magnetic field. Once we remove the exciting magnetic field, during the period of return to the initial equilibrium state, the protons emit a magnetic relaxation field that can be measured on the surface, constituting the RMP signal; The higher the signal, the greater the number of protons that have entered resonance and, therefore, the more important the water content. For this specific case, this method is the most useful, since its strong point is that the ability to find water confined in aquifers; On the other hand, if it were to be used only to detect and find geological structures, it would have to be complemented with other geological methods.

In conclusion, if previous studies of the area are well carried out and one of the three scientific methods previously exposed is found, finding the presence of groundwater would have a high probability of success.

4.3. Drillings

The next step to the detection of water is the drilling procedures. The most used technology to reach great depths of up to almost 300 m is the mobile platforms. These platforms move to the drilling point and drill the earth, crush the rock, drown the softer terrain... The extracted material is brought to the surface by an air compressor. There are other drilling methods such as the use of high-pressure water in some specific types of terrain, but drill bits and hammer punches are the most commonly used methods.

It is necessary to make a PVC or metallic jacket for deep perforations. This step prevents the collapse of the well, in the perforations with more unstable terrain it is necessary to use a metallic jacket although this makes the price more expensive. Finally, a gravel filter must be placed between the soil and the jacketed, so when it rains the water will seep into the aquifer and not contaminate it.

4.4. Main principles of solar water pumping

Pumping with photovoltaic energy is widely used and is a known technology, its uses are for drinking water consumption, small irrigation fields, livestock feed, swimming pools or medium industries. In this section, the relevant concepts for a correct sizing of such a system will be explained.

4.4.1. Pressure (Total manometric head (h))

The pressure or in this case the head (h) is the minimum force that the pump must provide to be able to transport a liquid from one point to another. In other words, it is the minimum pressure to be overcome by the pump.

In a pumping system the manometric height is obtained taking into account the following parameters, considered as lengths:

- **Static or geometric height (H_g)**: it is the vertical distance from the water level in the borehole to the highest point at which the water must reach.
- **Dynamic height (H_d)**: this is the result of pressure drops (due to friction) when the liquid flows through a pipe. These losses depend on the length of the pipe, its diameter and the coefficient of friction which depends on the roughness of the inner surface of the pipe ... Accessories for pipes also provide additional pressure losses.
- **Drawdown (S_w)**: The drawdown is the difference between the static or stable water level and the instantaneous level under specific pumping conditions (dynamic level). In some boreholes, the drawdown can reach 30 m or even more under normal operating conditions.
- **Depth from the point of the extraction point to the drawdown level (d_{pump})**: This parameter is the difference in height between the water level when the drawdown occurs and the setting point of the pump.

  The pump must always be submerged to avoid damaging it (suck air). The pump should not be close to the bottom to prevent it from clogging by sucking sand.

The manometric height is obtained by the following formula:

$$h = H_g + H_d + S_w - d_{pump} \qquad \textbf{(Eq. 4.1)}$$

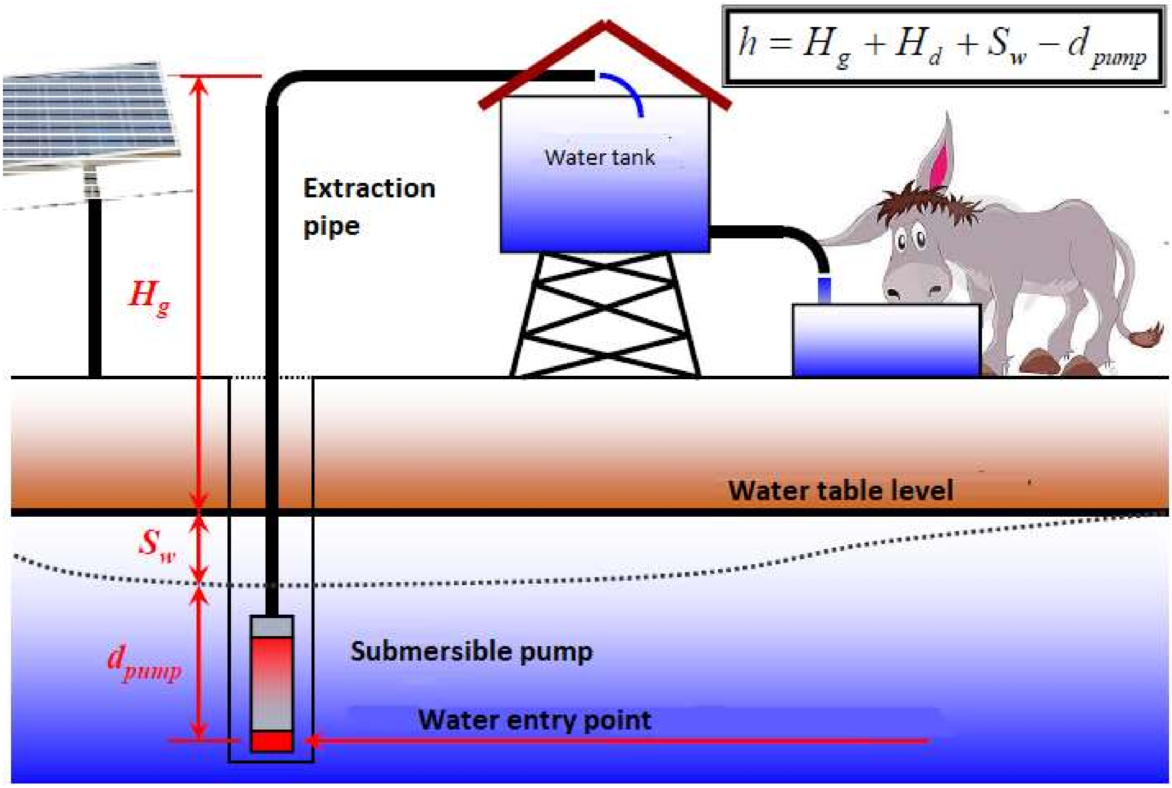

Figure 4.5: Diagram of a solar pumping system (ENRE, EEBE - UPC)

4.4.2. Flow rate

The flow rate is the amount of water that flows in a given time, it can be expressed as mass flow rate (kg/h) or volumetric flow rate (m^3/ h), this second being the most used in the pump catalogues.

The flow of water extraction from the subsoil has two limitations. The first is given by the necessary consumption, that is, one does not have to extract more water than is really needed. Secondly, a limitation is found due to the characteristics of the aquifer, it is not recommended to draw more water than it's naturally regenerated since otherwise it will be depleted.

For the establishment of the limit set by the consumption, it will be necessary to calculate an approximation of the future demand with a safety factor that will depend on the nature of the project and the hours of operation of it will depend on the solar resource in the area calculated by means of the PSH(Peak Solar Hours).

The water needs and the size or volume of the tank can be obtained as following:

$$W_{needs}[l] = V_{Tank} = daily\ needs\ \left(\frac{l}{day \cdot user}\right) \cdot N_{users} \cdot safety\ factor \cdot autonomy\ (days) \qquad \textbf{(Eq. 4.2)}$$

$$Q\ [l/h] = \frac{V_{Tank}}{PSH} \qquad \textbf{(Eq. 4.3)}$$

Where:

$W_{needs}[l]$= Water needs

V_{Tank}= Volume of the water tank

N_{users} = number of users

$Q\ [l/h]$= flow rate

PSH= Peak solar Hours

On the other hand, the extraction flow can be predicted by means of a subsoil study although its true value is determined by the pumping test once the drilling is done, this pumping test is explained in more detail in annexes.

Regarding the applications that have an intermittent pumping that does not work for 24 hours a day, as is the case in this study, it is possible to increase the limit flow of the aquifer. The pumping test really gives the value of the removable limit flow for 24 hours in a row and the aquifer is filled continuously. Therefore, if the pump runs less hours a day, more flow can be extracted without running out of groundwater. If this reasoning is carried out, it is not recommended to exceed the limit value marked by the pumping test in a wide way since it would cause a large reduction that can cause problems such as leaving the pump running in a vacuum.

4.4.3. The water pump power

The power of the pump will allow you to raise the flow you want to raise and you will have to exceed the total manometric head. The procedure to determine the model and therefore the power of the pump is determined by abacus provided by the different manufacturers.

Taking into account the value of the gravity acceleration $\left(g = 9{,}81\frac{m}{s^2}\right)$, The hydraulic power (Ph) required to pump water at a flow rate (Q) at a height (h) is obtained as following:

$$P_h = g \cdot Q \cdot h \qquad \textbf{(Eq. 4.4)}$$

Therefore, the electric power (Pe) of the water pump is related to the hydraulic power by the average efficiency of the subsystem motor-pump. The efficiencies values mostly used during the sizing process of these water pump are 60% for DC pumps and 40% for AC pumps. In addition, it will be needed to oversize of 10-20% as a safety factor in case the conditions of the borehole requires a slightly larger pump.

$$P_e = \frac{P_h}{\eta_{pump}} \cdot 1{,}2 \qquad \textbf{(Eq. 4.5)}$$

Figure X shows an example of the ENRE subject of the Energy Engineering degree for a flow of 2.21 m^3/h and a manometric height to exceed 25.96 m, obtaining a pump with a nominal power of almost

350W. In the same way it is possible to compare different types of pumps, brands, models ... Different abacus are provided by the manufacturer to ease the buyer's choice of the pump model.

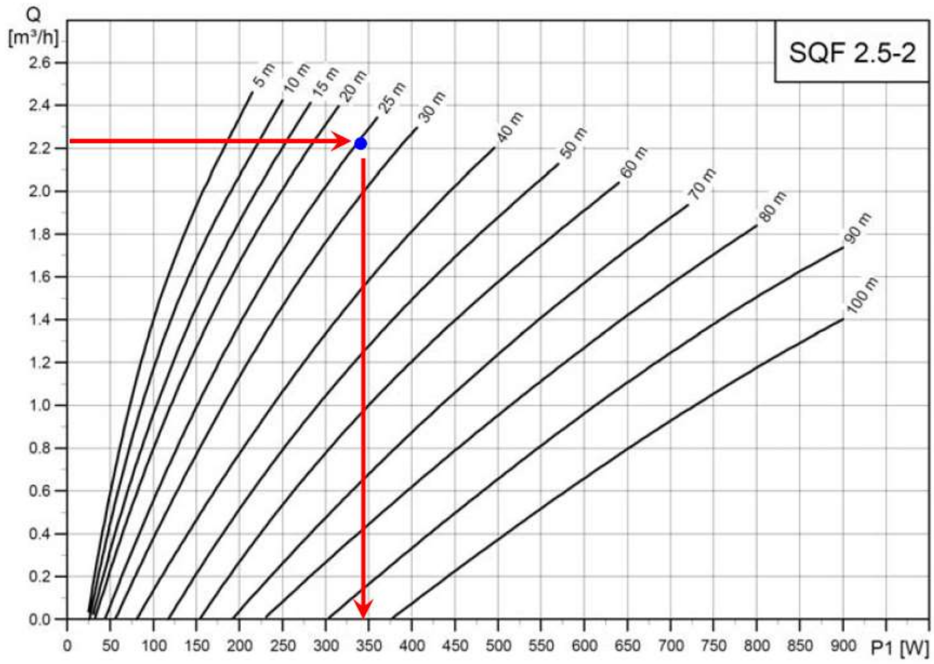

Figure 4.6: Power vs Flowrate curves, pump selection. Source: ENRE,EEBE-UPC

Once the pump model and its power have been selected, it is recommended that the diameter of the pipes be the same as that of the pump outlet, it is also recommended that the bore diameter be slightly larger than the external diameter of the pump.

4.4.4. Installed photovoltaic power

To ensure the proper an efficient functioning of the facility, a correct sizing of the photovoltaic panels is necessary. The first step is to obtain the solar resource in the locality of the project through the data obtained on the website of the Photovoltaic Geographical Information System (PVGIS), introducing latitude and the length of the location of interest we can obtain the irradiance and irradiation data with which the peak solar hours for a typical day of each month of the year will be obtained. The data obtained on this website will also subsequently serve to estimate the energy provided by the photovoltaic system at the optimum inclination of the panels.

Thanks to the irradiance data, the PSH can be calculated, these being the number of hours that an irradiance of 1000 W/m^2 should be to match the daily energy actually incident in that locality.

Once the available solar resource is obtained, it is necessary to calculate the required energy that the panels must provide to power the pump. This will be obtained evaluating the electrical energy consumed by the pump given its peak power and taking into account wiring losses (10%) and the total losses of the installation.

$$E_{pump}\left[\frac{Wh}{day}\right] = P_{pump} \cdot \frac{PSH}{day} \qquad \textbf{(Eq. 4.6)}$$

Applying wiring losses:

$$\mathrm{C_{req}}\left[\frac{Wh}{day}\right] = 1{,}1 \cdot E_{pump} \quad \textbf{(Eq. 4.7)}$$

The installation losses are calculated using the following formula:

$$K_T = [1 - (K_B + K_C + K_R + K_X)]\left[1 - \frac{K_A D_{aut}}{P_{D,max}}\right] \quad \textbf{(Eq. 4.8)}$$

If the system is sized without considering batteries, some parameters of this equation can be eliminated to obtain the following equation:

$$K_T = [1 - (K_R + K_X)] \quad \textbf{(Eq. 4.9)}$$

The required energy to be generated by the photovoltaic panels is therefore:

$$C'_{req} = \frac{\mathrm{C_{req}}}{K_T} \quad \textbf{(Eq. 4.10)}$$

$$\mathrm{C'_{req}} = \frac{\mathrm{C'_{req}}}{V_{nom}} \quad \textbf{(Eq. 4.11)}$$

Knowing some of the properties of the panel such as the maximum voltage (V_{mp}), the maximum current (I_{mp}) and the efficiency (η) of the panel to be installed, it is possible to find the maximum possible to generate using one panel:

$$E_{panel} = \eta \cdot I_{mp} \cdot PSH \quad \textbf{(Eq. 4.12)}$$

Subsequently, the number of panels required in series (nps) and in parallel (npp) can be obtained using equation Eq.4.13 and Eq.4.14, haven established the nominal voltage (V_{nom}) of the installation. The multiplication of these two results will finally establish the total number of solar panels required (Eq.4.15).

$$n_{pp} = \frac{C'_{req}}{E_{panel}} \quad \textbf{(Eq. 4.13)}$$

$$n_{sp} = \frac{V_{nom}}{V_{mp}} \quad \textbf{(Eq. 4.14)}$$

$$N_{total} = n_{sp} \cdot n_{pp} \quad \textbf{(Eq. 4.15)}$$

4.4.5. Energy storage

There are two types of storage for these applications; by battery and water tanks. In both cases the dimensioning will depend on the days of autonomy recommended for the use of the installation and its location. For example, a medical clinic isolated from the distribution network will need a high number of days of autonomy and an animal farm, less.

The use of batteries involves a high investment cost, it is recommended when the battery is also used to manage the flow of electrical energy of a house or similar. Otherwise the most optimal system is a tank. This tank can be placed in high if pressure is needed to travel long distances of pipe or feed a building site.

In Cameroon, the most used system is high deposits, the main objective of these is to raise water from the distribution network or from a well to use it in case the electrical system falls. First, there are large concrete tanks (Fig 4.7) to feed some neighbourhoods and then there are those belonging to private individuals of PVC (Fig 4.8), the latter have a useful life of 5 years.

As mentioned previously in point 4.4.1, The size or volume of the water tanks can be obtained using equation Eq.4.2.

Figure 4.7: Tank of concrete Douala, Cameroun. Source: Own picture

Figure 4.8: Tank of PVC Douala, Cameroon. Source: Own picture

5. Solar water pumping systems

5.1. Solar water pumps systems

Solar ware pumps can supply water to locations with difficult access of water piping or power lines. The obtention of water in these areas mostly require the intervention human or animal effort or the usage of fuelled engines to pump water from a borehole. Solar water pumps are an environmentally and socially interesting technology to obtain and supply reliable and clean water for various applications such as drinking water, livestock, household usage or irrigation.

A solar water pump system is basically an electrical pump system in which the electrical energy required to power an electric motor (electric pump) is acquired from solar photovoltaic panels. These pumps can be submerged or used at the surface. The water most of the times I pumped from the ground or stream and stored in an elevated tank that provides a gravity feed to later on ease the distribution of water to further spots and at the needed pressure.

A solar water pumping system consists of three main components:

- A solar module or various modules which provide the power
- A controller which controls the system
- A pump coupled to a motor

Some advantages of the solar pumping systems are their low maintenance, no fuel costs, easy installation, simplicity and reliability, stand-alone system, eco-friendliness, absence of noise and their easy mobility. On the other hand, some disadvantages are their high initial costs, low output in cloudy weather, must have a good solar exposure within at least 5 hours per day.

5.2. Types of solar water pumps

Solar water pumps can be classified according to three aspects. Firstly, their technological construction. There are two major types: Helical rotor pumps and centrifugal pumps. Secondly, regarding their location in relation to the source of water. There are two types: submersible and surface pumps. Lastly, according to the required electric motor. There are two types: Direct Current (DC) pumps or Alternating Current (AC) pumps.

Before selecting the most suitable pump for a solar water pumping system, it is recommended to take into account various factors such as: the available hydric and solar resources of the chosen area, the users and form of usage that will be given to the water, the required flow rate and its most adequate distributing system and the calculations of the pressure losses and the needed power.

5.2.1. Types of pumps regarding their technological construction

5.2.1.1. Helical rotor pumps

In a helical rotor pump, the helical rotor rotates inside a rubber stator. There is a small cavity between these two parts which moves from one end to the other. Each rotation provokes a small amount of water is forced through the pump. These pumps work best for applications requiring low to medium flow rates at high hydraulic heads. The helical rotor pump provides high head even at low rpm, this ensures the pumping of water to the surface even with low available power o irradiation. Helical rotor pumps have a higher hydraulic efficiency than centrifugal pumps of same flow rate.

5.2.1.2. Centrifugal pump

This technology of water pump contains a spinning impeller. Water enters the centre of the pump and is pushed outwards. They are suitable for wells of small depths. This type of pump is generally used for high flow rates and low hydraulic heads.

Figure 6.1: Helical rotor submersible water pump. Source: www.lorentzpumps.co.za

Figure 5.2: Submersible Centrifugal water pump. Source : www.lorentzpumps.co.za

5.2.2. Types of pumps according to their location in relation to the source of water

5.2.2.1. Submersible pumps

They are mostly used for pumping water from bores. The pump needs to be placed underwater. They fit inside the bore casing in the drilled hole. Submersible pumps are highly efficient and more silent than surfaced pumps.

5.2.2.2. Surface pumps

They can be placed at the side of a lake or any other water reserve. They are not suitable for suction and can only water from about 6 vertical meters. Surface pumps are cheaper than submersible pumps. A surface pump allows easy access to itself and it is much more exposed to bad environmental and climate conditions, theft and vandalism.

Figure 7: Surface solar water pump. Source: www.lorentz.de

5.2.3. Types of pumps according to the required electric motor

5.2.3.1. Direct current (DC) pumps:

Since solar panels produce electricity in direct current. The energy can be used directly to power the pump. DC pumps are more efficient than AC pumps because there is no power loss, for there is no need to convert the generated energy. However, DC pumps are more expensive and the maintenance and reparation are quite difficult in remote areas.

5.2.3.2. Alternating current (AC) pumps:

An AC pump requires an inverter to convert DC generated energy to AC, to later on power the pump. The implementation of the inverter leads to power losses due to the conversion from DC to AC.

6. Implementation of the water borehole

6.1. Introduction

About 71 percent of the earth's surface is covered with water. Water is concentrated at the Earth's surface, it's relative mass in comparison to the Earth is small (0,02% of the Earth's mass). 96,5% of the Earth's water Is located in oceans; 2,5% is freshwater and 1% is saline groundwater and saline lakes.

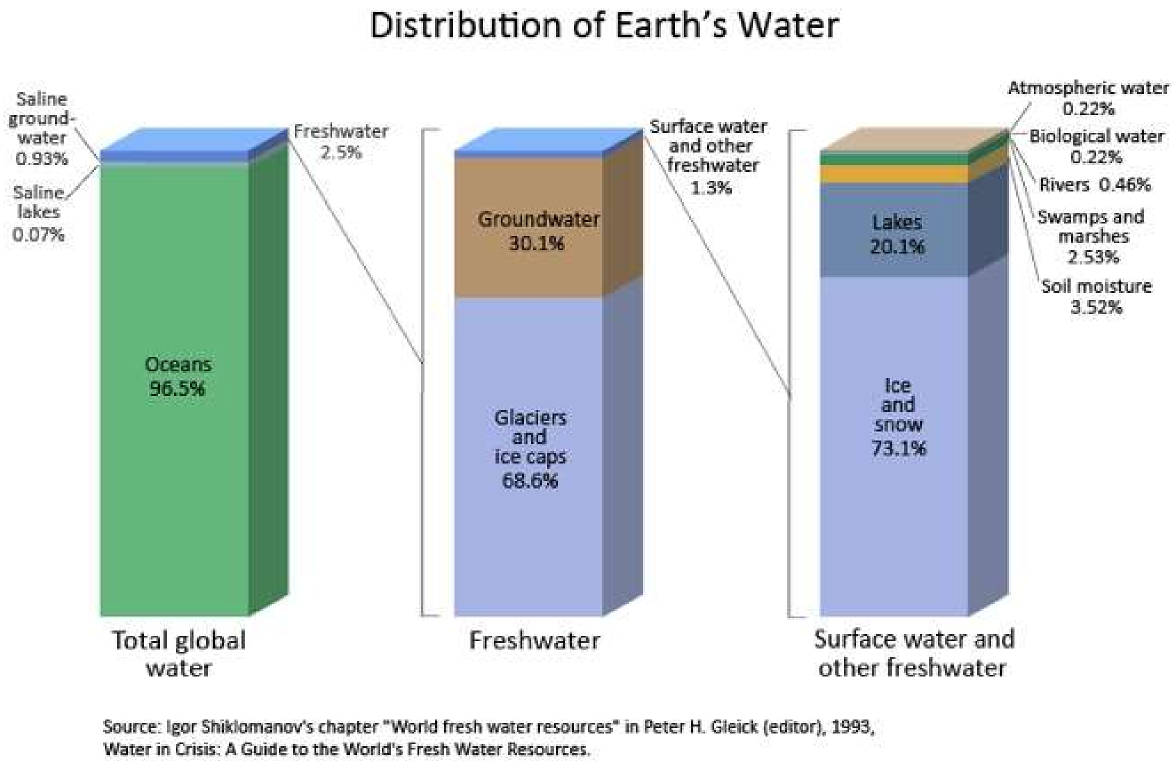

Figure 6.1: Distribution of water on Earth: Source: Water in Crisis: A Guide to the World's Fresh Water Resources

From the freshwater available on Earth, 69% is in form of ice cap and glacier. Only about 31% is accessible for drinking (0,775% of the Earth's water) this water is located in lakes, rivers, streams, etc. The available drinking water except from glaciers is groundwater. Groundwater the streams and saturated wetlands. It provides nearly 40% of drinking water.

Of the less than 1% of water available to drink, most third world countries do not have a proper and safe access to it. According to World Health Organization (WHO), in 2017, *785 million people lack even a basic drinking-water service, including 144 million people who are dependent on surface water. Globally, at least 2 billion people use a drinking water source contaminated with faeces.*

Contaminated water favours to transmission of diseases such as cholera, dysentery, diarrhoea, typhoid, etc. Contaminated drinking water is estimated to cause 485.000 diarrheal deaths per year.

6.2. Groundwater

Groundwater represents approximately 21% of the volume of freshwater existing and accessible on the continents and this water is found in aquifers below the earth's surface. This water is an important resource and supplies one third of the world's population. This water is affected by pollution and overexploitation.

Groundwater comes from precipitation that seeps through various levels of cracks and pores in rocks and sediments found beneath the earth's surface and accumulates in porous subsoil rocks (aquifers). Groundwater tends to be fresh and drinkable due to this natural depuration of particles and contaminating microorganisms. Sometimes, these aquifers are contaminated by human activity, due to the construction of septic tanks or the use of fertilizers (nitrates and chemical fertilizers) for agriculture.

6.3. Groundwater studies results

The methods or procedures of water detection can be rudimentary as are *water diviner* techniques or more sophisticated as the preliminary analysis of satellite photographs or the study of proton magnetic resonances. Nowadays, geophysical methods are the main procedures for groundwater prospecting and detection.

The geophysical techniques of groundwater prospecting conducted in the field of implementation of this project consisted in the appreciation of the magnetic susceptibility of subsoil rocks. With this method, the sensitivity of rocks to magnetization due to electromagnetic signals emitted by magnetic induction is being measured.

The aim of the study was to find areas where the alterations and fractures of the bedrock are sufficiently developed to favour the accumulation and circulation of groundwater.

The tasks carried out to carry out the prospection are the following:

1- Search for structures with an appreciable hydrogeological potential
2- Data collection
3- Recognition of the basin and geological structures.
4- The search for hydrogeological indices (sources, alignment of tall trees...)
5- Carrying out the tests (geoelectrical study) on the site.

6.3.1. Description of the methodology

In the first place, we started with the hydrogeological study observing the relief of the zone to note the different hydrogeological and piezometric indices.

Subsequently, the methodology applied in the phase of geophysical prospecting is electric sounding. It consists in the use of continuous or alternating currents at low frequency in order to understand the structure of the rocks in the subsoil thanks to the study of the electrical resistivity of the formations of which they are formed. Electrical resistivity is an important parameter in hydrogeology since in most porous rocks, the pores are full of electrolytes that conduct electric current.

In the electrical sounding carried out, two current emitting electrodes A and B and two other potential measuring electrodes M and N were used. Between the electrodes M and N, the potential difference due to electrodes A and B is measured. The measurements are repeated each time increasing the length of the A-B emission line, keeping the centre of the device fixed. The measured values of apparent resistivity as a function of the length of the A-B transmission line are represented graphically afterwards.

6.3.2. Results

The results of the hydrogeological and geophysical study indicate a well refurnished aquifer and confirm the possibility of drilling and finding water with a success rate of 80% at an estimated depth of 80 to 85m with a flow rate between 1 to 1.5 m3/h. The graph with the numbers 5 and 10 describes the two fracture zones in the rocky levels of the subsoil, corresponding to 36 and 72m depth. The details of the prospecting study can be found in the document attached in the annexes.

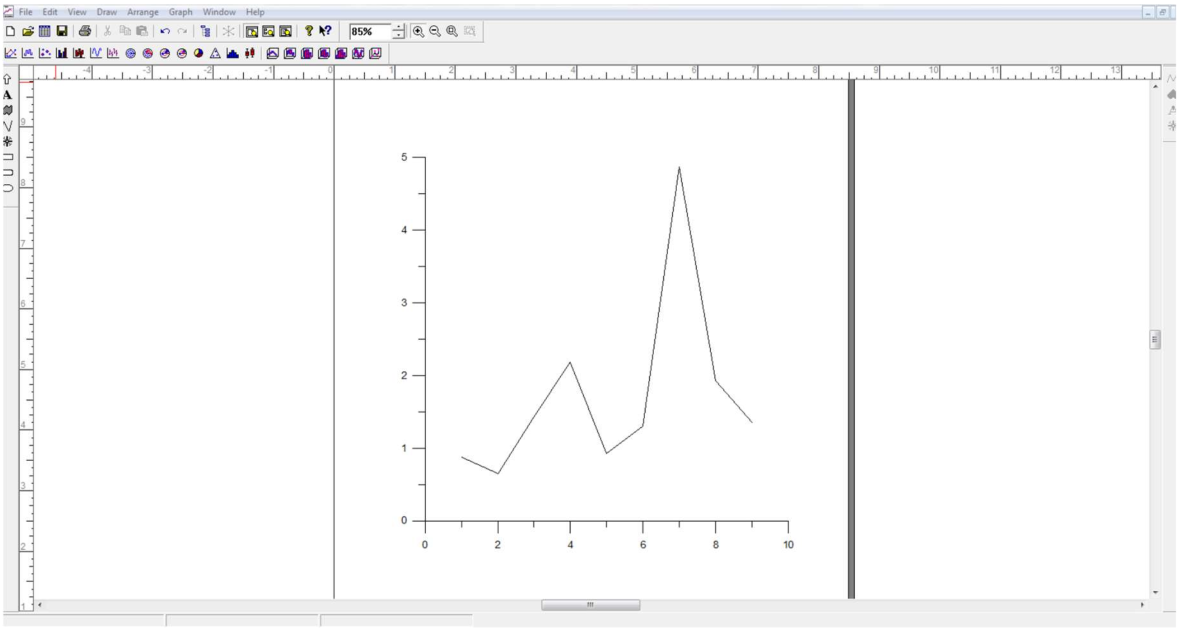

Figure 6.2: Geophysical study result: Fracture zones. Source: CIS BTP Sarl

6.4. Drilling and casing

After finding the drilling point to reach the aquifer, we proceed to the drilling. For this project, a drilling machine (Fig.6.3) was used with which two methods were used, the rotary for soft ground and the rotary percussion-assisted for hard ground.

The perforation is made by coupling the perforating tips to multiple bars of 4.60m each. The first stage of drilling consists of using a triangular rotary drill bit (Fig. 6.4) to pierce through the soft ground. When it reaches the rocky subsoil level, 1" structural metallic casing tubes are coupled and introduced. This tube strengthens the walls during drilling to prevent the walls from collapsing. During drilling, compressed air will be injected to extract soil and fragments of pulverized rock to the surface.

Approximately 27m of soft soil is penetrated, after which we come into contact with the rocky level of the subsoil. When this level is reached, the triangular bit is replaced by a rotary hammer bit (Fig.6.5). Rock drilling (granite) continues. At a depth between 52 m to 67 m, a small bag of water is found between two rocky levels. The water that comes out in this situation is dirty and the flow is low. At a depth of 67, a rock is penetrated up to a depth of 76 m. The drilling is completed at a depth of 78.6 m when it is noticed that the colour of the water is gradually clarifying and the flow is greater, but remains dirty due to the agitation of the aquifer. The total amount of bars introduced is 17.

Figure 6.3: Drilling machine. Source: Own Picture

Figure 6.4: triangular drill bit. Source: Own Picture

Figure 6.5: hammer drill bit. Source: Own Picture

Figure 6.6: The drilling machine piercing through the rocky ground and expelling the fragments of the pulverized rock. Source: Own Picture

In view of the geophysical study report, it has been judged that the flow of withdrawable water is significant at a depth of 78.6 m and the possible hydrogeological changes that may occur in the subsoil at a greater depth could lead to the loss of this flow. The well casing is then pursued. The PVC pipes (125 mm in diameter and 3 m in length each) are coiled together to reach a depth of approximately 80 m in the borehole (Fig.6.7).

In order to prevent the fine particles that form part of the soil from entering the well and being carried away by the water, the water must be filtered through a layer of gravel that is placed between the wall of the well and the casing. This process prevents the quality of the water from being affected and the pump from being damaged. once the casing is finished, the protruding part of the tube is covered to ensure the safety of local residents (Fig.6.9;6.10).

Figure 6.7: Borehole casing. Source: Own Picture

Figure 6.88: Borehole casing. Source: Own Picture

Figure 6.9: Covering of the borehole. Source: Own Picture

Figure 6.10: Drilling and casing completed. Source: Own Picture

6.5. Pump test

Once the drilling and piping are completed, the aquifer is left to settle for 5 days for the decanting, in order to separate the solid fragments from the water. Next, the pumping test must be carried out to predict the fluctuations in the aquifer for each season of the year. It allows to have a more concrete idea of the value of the maximum withdrawable flow rate from the borehole and also the depth at which the pump should be placed in order to ensure that it is always submerged in water during periods of low water level in the aquifer.

The pumping test basically consists of extracting water from the well at different flow rates (between 1 and 3 m3/h) with an electric submersible pump. Before introducing the pump, the static head (Hs) of the borehole has been measured. It is 42.47 m. The static head is the Depth of the water level in the borehole, in absence of any pumping.

The electric pump inserted is an ASTRAL brand pump (1,5 HP; Fig.6.11) and it is powered by a 7 HP generator set (Fig.6.12). After the installation of the pump, it was started and the starting flow rate was established using a 10-litre container and a stopwatch.

After carrying out the different tests and analysing the measured data, the following results were obtained:

- Maximum drawdown: 43 m
- Static water level of the borehole at different flow rates: 17,5 m (1 m^3/h); 25,18 m (2 m^3/h) and 32,57 m (3 m^3/h)
- The maximum withdrawable flow rate: 2,47 m3/h
- The minimum depth of the pump in the borehole: 70 m

Figure 6.11: Introduction of the pump for the pumping test. Source: Own Picture

Figure 6.129: containers to realize the pumping test. Source: Own Picture

Figure 10: Generator set to power the pump. Source: Own Picture

6.6. Water quality

In order to carry out this quality test, a sample of water had to be taken from the borehole and sent to a laboratory specialised in water physico-chemical analysis (Laboratoire de Baleng, located in Bafoussam). After the organoleptic and bacteriological analysis of the water sample, it was revealed that the water is chemically satisfactory. It is poor in mineral salts and pollution indicator levels (nitrite, ammonia...), anions, cations, chlorine, heavy metals and other toxic parameters... met the standardized ranges. The analysis also confirmed the absence of dangerous bacteria for the human organism. The detailed report of the physical-chemical analysis can be checked in the annexes.

7. Design process and technical calculations

7.1. Problem statement

The population of Banenkane of about 2000 inhabitants requires a solar water pumping system to supply the drinking water needs of this population.

The sizing of the system to implement will be done by considering the daily consumption of drinking water of the population, the solar resource of Banekane and characteristics of the borehole specified by the pumping test.

7.2. Dimensioning of the pumping system

7.2.1. Required water consumption

According to the World Health Organization, in the document Domestic Water Quantity, Service, Level and Health, it is stipulated that the minimum daily amount of drinking water required for hydration via direct ingestion or food is 2 litres for an adult male, 1.4 litres for an adult female and 1 litre for a 10-year-old child.

Using the equation Eq.4.2, and considering a daily consumption of 2 litres, applying a safety factor of 20% and 2 days of autonomy, it is obtained that the daily need of water is of:

$$W_{needs} = \frac{2\ l}{day \cdot inhabitant} \cdot \frac{2000\ inhabitants}{1} \cdot 1{,}20 \cdot 2\ days = 9600\ l \qquad \textbf{(Eq. 7.16)}$$

$$W_{needs} = W_{needs} = 9600\ l \qquad \textbf{(Eq. 7.2)}$$

The water needs and the volume of the water tank is thus 9600 litres. Consequently, in order to obtain standardized dimensions of the water tank, the calculated value is rounded up to 10,000 litres to make it easier to acquire in Cameroon. Since, in Cameroon, the most commonly commercialized tank sizes are 1,000; 2,000; 3,000; 5,000 and 6,000 litres, it has been determined that two tanks of 5,000 litres each will be used.

7.2.2. Solar Resource and Water extraction flow rate

Using the data obtained from the Photovoltaic Geographical Information System (PVGIS) website, introducing the latitude and longitude of the location of interest, we can obtain the irradiance and irradiation data with which the peak solar hours will be calculated for a typical day of each month of the year. The data obtained in this web will also serve later to estimate the energy provided by the photovoltaic system in the conditions of optimal inclination of the panels. In order to favour a better solar capture and to get the maximum performance from the solar panels it is important to tilt and orientate the panels properly over the surface where they will be mounted.

The optimal annual slope for a better exploitation of the sun is 9°. This value could be varied according to the energetic needs and the periods of the year when this need is higher. It has been decided to choose this slope angle because an equitable consumption of drinking water has been estimated annually because this water is only intended to be used as drinking water (drinking, cooking...). Moreover, Camerun is very close to the equator and the modules could work in an acceptable way with a slope of practically 0°. Since Cameroon is located in the northern hemisphere, it will be necessary to point the modules to the geographic south.

Coordinates of the location:

Latitud: 5,131° **Longitud**: 10,570° **Optimal slope**: 9°

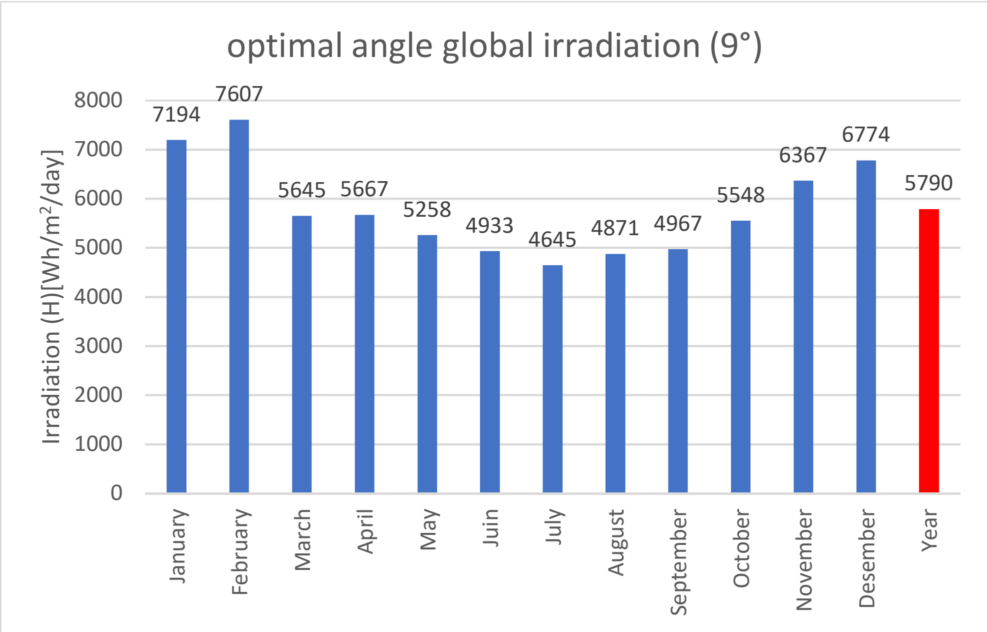

Figure 7.1: Optimal angle global irradiation

The graph (Fig.7.1) above collects the total irradiation data on a typical day of each month of the year on the inclined plane. The month with the highest radiation is February (7,607 Wh/m^2/day) while the month with the lowest radiation is July (4,645 Wh/m^2/day). The average annual irradiation is 5,790 Wh/m^2/day. Considering the equivalent peak solar hour (PSH) is equal to 1000 W/m^2, with the annual average value of the irradiation, it can be calculated by applying conversion factors that the design peak solar hours will be 5,79 hours.

The required extraction flow rate to fill the tank is calculated by performing the quotient between the daily volume required to fill the tank and the design peak solar hour defined in the previous paragraph (5.79 h). Applying equation Eq.4.3, the daily minimum flow rate is:

$$Q\ [l/h] = \frac{V_{Tank}}{PSH} = \frac{10.000\ l}{5{,}79\ h} = 1727{,}12\frac{l}{h} = 1{,}73\frac{m^3}{h} \qquad \textbf{(Eq. 7.3)}$$

The minimum daily flow rate to fill the tank, and thus the minimum flow rate of the water pump is 1.73 m3/h.

7.2.3. Construction of the Building

The Building to be constructed has the following main objectives:

- Raise the water tanks to a certain height to ensure good water pressure at the outlet of the taps.
- Ensure the safety of the panels, tanks and electrical and electronic equipment (solar and pumping controller, differential...), protecting them from vandalism and bad weather.
- To facilitate the distribution of water to the inhabitants of the locality by means of the taps that will be located outside.

The plans of the construction can be consulted in the annexes.

The construction steps were as follows:

From 06/08/2019 to 11/08/2019:

- Site preparation work: Establishment and delimitation of the foundation
- Excavation and installation of the footings.
- Excavation, placement of 20 cm blocks. Preparation and sinking of the first solid slab in reinforced concrete.

From 13/08/2019 to 24/08/2019:

- Placement of the first level posts and blocks
- Preparation and sinking of the second slab

From 03/09/2019 to not completed during the date of writing this document:

- Assembly of the solar panels support and installation of the solar panels
- Door placement
- Placing of the water tanks
- Installation of plumbing systems
- Pump installation
- Latest finalizations of the construction

Figure 7.2: The building almost completed. Source: Own Picture

7.2.4. Calculation of the manometric height (pressure losses and manometric height)

Equation Eq.4.1 shows the parameters to obtain the total manometric head or the effective pressure that the pump must overcome.

7.2.4.1. **Static or geometric height (H_g):**

La distancia vertical entre el nivel de agua en el pozo y la superficie del suelo es de 42,47 m (Informe de la perforación). La altura vertical entre la superficie del suelo hasta el punto ms elevado donde se bombea el agua es de 3,4 m.

$$H_g = 42{,}47 + 3{,}4 = 45{,}87\ m \qquad \textbf{(Eq. 7.4)}$$

7.2.4.2. **Dynamic height (H_d)**:

The dynamic height, equivalent in distance, due to friction losses in the PVC pipes and due to the use of fittings is calculated as follows:

The equivalent total length of the installation has to be calculated. This value includes the length of the pipe and the equivalent length for the use of fittings such as elbows, tees, check valves... The PVC pipes that will be used to carry the water from the aquifer to the tanks will have a diameter of 32mm. Choosing pipes with smaller diameters increases the friction load losses while pipes with larger diameters reduce the losses, but these imply higher costs.

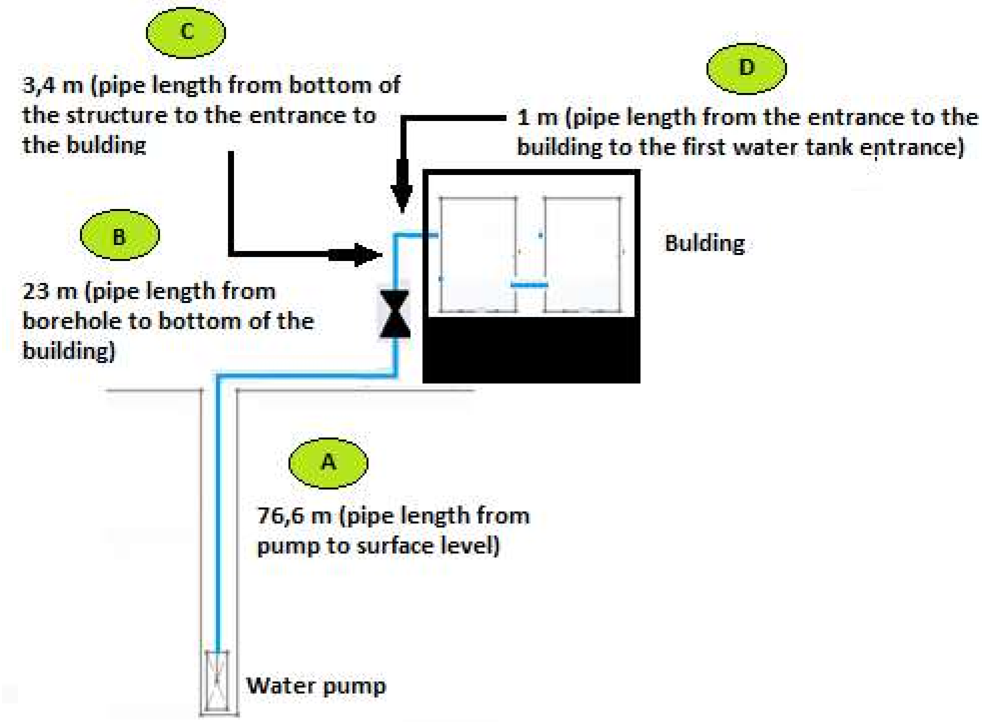

Figure 11: Installation Diagram. Source: Own Picture

Figure 31 describes the total length of the pipes:

$$L_{pipe} = 76{,}6 + 23 + 3{,}4 + 1 = 104\ m \qquad \textbf{(Eq. 7.5)}$$

In this installation, to transport the water from the aquifer to the tanks, 3 90° elbows (joining: A and B; B and C; C and D) and 1 check valve will be used. Each of these fittings has an equivalent length corresponding to the diameter of the pipe. These lengths can be seen in figure 31.

Table 7.1: Table of equivalent lengths of pipe fittings. Source: ENRE; EEBE-UPC

Diámetro	Codo 90°	curva 90°	válvula de pie	válvula retención	válvula compuerta
25	2	1	5	4	2
32	2,5	2	5	4	2
40	2,5	2	5	4	2
50	2,5	2	6	5	2
60	3	2	6	5	3
80	3	2	7	6	3
100	4	3	8	6	3
125	4	3	10	8	4
150	5	3	12	10	4
200	7	4	18	15	6
250	7	4	18	15	6

The equivalent length of the pipe fittings is:

Table 7.2: Fittings equivalent length

Fittings	**Ud.**	**unit length (m)**	**Total (m)**
Pipe (90º)	3	2,5	7,5
Check valve	1	4	4
Total equivalent length of fittings (L_{acc}):			11,5

The equivalent total length of the pipes in the system turns out to be:

$$L_{tot} = L_{pipe} + L_{acc} = 115{,}5\ m \qquad \textbf{(Eq. 7.6)}$$

Considering the flow rate values obtained in section 7.2.2 and the pipe diameter determined in the previous paragraph, the following abacus is consulted to determine the head losses due to water friction at 45°C for plastic, PVC or polyethylene pipes (figure X). It is therefore found that the losses are 20 mm of water column per metre of pipe (mm c.d.a/m). A pressure loss correction factor must be applied to this value for average water temperatures other than 45°C. Knowing that the water in the aquifer has a temperature between 5 and 10°C, the factors determined in table 3 have to be applied. In this case, it has been assumed that the water in the aquifer is 5°C.

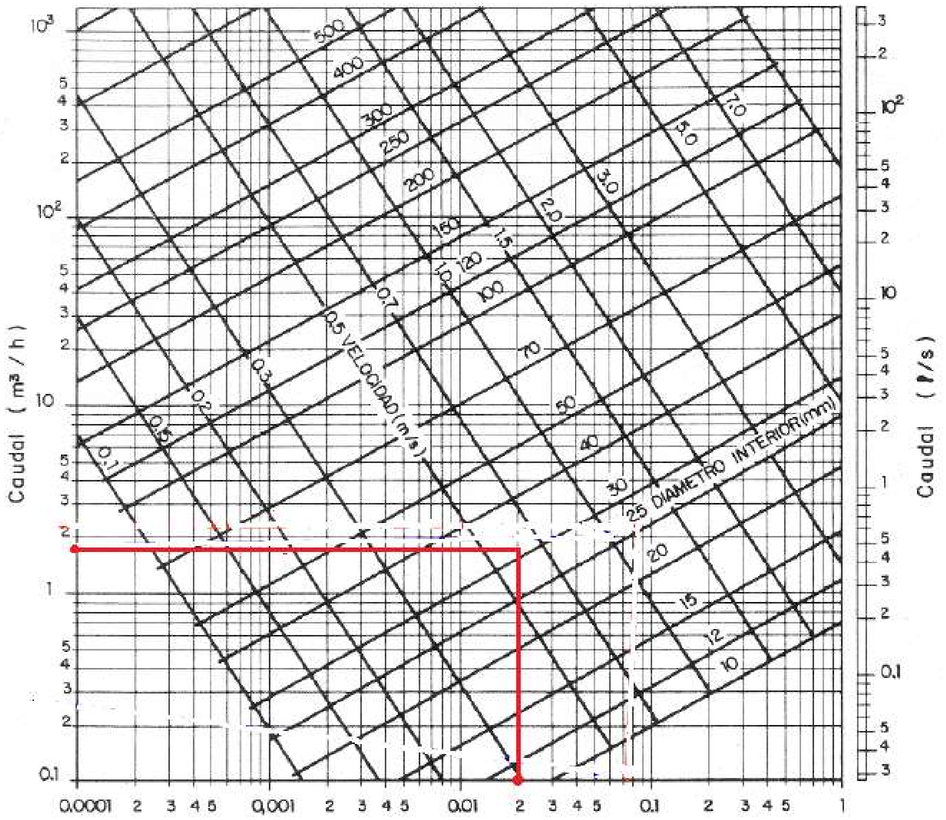

Figure 7.4: Abacus to determine friction losses in PVC pipes (Water at 45°C). Source: ENRE-EEBE-UPC

Table 7.2: Correction factors for friction losses at temperatures different from 45°C. Source: ENRE;EEBE-UPC

Temperatura del agua (°C)	5	10	20	40	45	50	60	80	90	95
Factor	1.24	1.18	1.09	1.02	1.00	0.99	0.96	0.92	0.91	0.91

The total dynamic height is obtained by operating as follows:

$$H_d(T = 45°C) = L_{tot} \cdot 20 \frac{mm\ c.d.a}{m} = 115{,}9 \cdot 20 \frac{mm\ c.d.a}{m} \qquad \textbf{(Eq. 7.7)}$$

$$H_d(T = 45°C) = 2.318\ mm\ c.d.a = 2{,}310\ m\ c.d.a \qquad \textbf{(Eq. 17.8)}$$

$$H_d(T = 5°C) = 2{,}318\ m\ c.d.a\ \cdot 1{,}24 = 2{,}864\ m\ c.d.a \qquad \textbf{(Eq. 7.9)}$$

The total Dynamic head (H_d) is 2,874 m.

7.2.4.3. Drawdown (S_w) and Depth of the pump (d_{pump}):

According to the pumping test carried out, the drawdown with an extraction flow rate of 1 m3/h is 12.95 m. Working with flows of 2 m3/h and 3 m3/h, the respective drawdown levels are 25.18 m and 32.57 m. For this scenario, since a flow rate of 1.727 m3/h is closer to 2 m3/h than 1 m3/h and in addition the maximum withdrawable flow rate from the borehole is 2.47 m3/h, the drawdown associated with 2 m3/h, i.e. 25.18 m, will be applied.

The depth of the pump is the distance between the intake point of the pump and the water level when the drawdown occurs in stationary state. The pump's intake point is 77.86 m (drilling depth subtracting 0.75 m to separate the pump from the bottom of the aquifer).

$$d_{pump} = 77{,}86 - (S_w + H_s) = 77{,}86 - (25{,}18 + 42{,}47) = 10{,}21\ m \qquad \textbf{(Eq. 7.10)}$$

Once all these parameters have been obtained, the gauge height can be obtained by applying the equation Eq.4.1:

$$h = 45{,}87 + 2{,}865 + 25{,}18 - 10{,}21 = 63{,}705\ m \qquad \textbf{(Eq. 7.1118)}$$

The pump to be chosen shall have a head greater than 63,705 m.

7.2.5. Hydraulic Energy, Hydraulic and electric power required from the water pump

The hydraulic energy (E_h) to move a volume (V) of liquid at height (in this case the total manometric head) can be obtain applying the following equation.

$$E_h = \rho \cdot g \cdot V \cdot h \qquad \textbf{(Eq. 7.12)}$$

$$E_h = 1000 \frac{kg}{m^3} \cdot 9{,}81 \frac{m}{s^2} \cdot 10\ m^3 \cdot 63{,}705\ m \qquad \textbf{(Eq. 7.13)}$$

$$E_h = 6.249.433{,}267\ J = 6249{,}433\ kJ = 1{,}736\ kWh \qquad \textbf{(Eq. 7.14)}$$

The hydraulic power (P_h) required to pump water at a flow rate (Q) at a height (h) is obtained as following:

$$P_h = \rho \cdot g \cdot Q \cdot h \qquad \textbf{(Eq. 7.1519)}$$

$$P_h = 1000 \frac{kg}{m^3} \cdot 9{,}81 \frac{m}{s^2} \cdot 10 \frac{m^3}{s} \cdot 63{,}705\ m \qquad \textbf{(Eq. 7.1620)}$$

$$P_h = \rho \cdot g \cdot Q \cdot h = 299{,}837\ W$$ **(Eq. 7.1721)**

The Electric power (Pe) needed by the water pump. It is related to the hydraulic power by the average efficiency of the subsystem motor-pump. The efficiencies values mostly used during the sizing process of these water pump are 60% for DC pumps and 40% for AC pumps.

$$P_e = \frac{P_h}{\eta_{pump}}$$ **(Eq. 7.18)**

$$P_e = \frac{299{,}837}{0{,}6} = 499{,}728\ W$$ **(Eq. 7.19)**

It is recommended to oversize the system by applying 10% or 20% factor on the electrical power of the pump. The oversizing is done to prevent any future shortage that the system may have to pump, especially for the first suction.

$$P_e = 499{,}728\ W\ \cdot (1{,}20) = 599{,}673\ W$$ **(Eq. 7.20)**

Once these calculations have been made, all the values necessary to choose the water pump of the system are available. These values are the minimum requirements to be met by the pump.

Table 7.3: Minimum requirements to be met by the pump

Minimum requirements of the water pump	
Flow rate (m^3/h)	1,727
Total Hydraulic Head (m)	63,705
Electric power (W)	599,673

7.2.6. Water pump choice

Due to a lack of equipment from reliable manufacturers, it was necessary to choose a pump with properties far above those required. The model chosen is the SQF-2.5-2 from the Danish brand Grundfos. Grundfos operates globally and are recognised and have a reputation for reliability and efficiency. Grundfos products are not the cheapest but the quality is flawless. Locally, experts in the pumping sector advise selecting this brand despite the high cost, but they guarantee its long-term effectiveness in the system.

The SQFlex pump with a helical rotor is suitable for high heights and low flow rates. The SQFlex system is a reliable water supply system based on renewable energy sources such as solar and wind power. Thanks to its flexible power supply and performance, the SQFlex system can be combined and adapted to meet any installation site requirement. The SQFlex system has a wide voltage range, Maximum Power Point Tracking (MPPT) as well as protection against dry run, voltage and overload. The chosen pump has the following technical features:

Table 7 4: Solar water pump's specifications

Model number:	SQF 2.5-2
Type:	Helical rotor
Rated power:	1,4 kW
Rated voltage:	30-300 VDC or 90-240VAC at 50/60 Hz
Rated current:	8,4 A
Maximum flow rate:	11 GPM; 2,5 m^3/h; 2500 l/h
Maximum head:	394 ft.; 120 m
Liquid max. temperature	40°C
Weight:	22,5 lbs; 10 kg
Dimensions:	Length: 49,09''; 1,247 m Wide: 2,91''; 0,074 m

7.3. Dimensioning of the solar photovoltaic system

In the following section, the required calculations will be made to size the photovoltaic solar system in order to meet the energy demand of the chosen pump. Basically, the number of modules to be installed, the technical properties of the controller to connect between the photovoltaic panels and the water pump, and the electrical protections to be installed will be determined.

7.3.1. Installed capacity of the solar array (Calculation)

By consulting the technical data sheet of the pump it has been found that in direct current the pump is operational when it receives a voltage in the range of 30 to 300V and a nominal current of 8.4A. Working with high voltages leads to the use of lower wiring sections and allows electrical losses to be reduced. The Grundfos brand controller that was bought with the pump is programmed by default to work with it. The manufacturer of the controller recommends working at voltages above 120V so that the controller can operate more efficiently. Due to this specification, the sizing will be done considering 120 V as the nominal voltage of the installation.

To find the required number panels we will look for the ones needed in series (nps) and those in parallel (npp). The multiplication of these two results will be the total number of panels. The following steps will help us obtain this value.

Applying equation Eq.4.6, the energy consumed by the pump is:

$$E_{pump} = 1400W \cdot \frac{5{,}79\ h}{day} = 8.106\ Wh \qquad \textbf{(Eq. 7.21)}$$

Considering the energy losses through to the wired connections (10%) (using Eq. 4.7):

$$\mathrm{C_{req}} = 1{,}1 \cdot E_{pump} = 8916{,}081 \frac{Wh}{day} \qquad \textbf{(Eq. 7.22)}$$

The total losses of the installation must be calculated applying equation (Eq.4.9), since the system runs without batteries. Applying common values of losses due to the performance of the regulator and losses due to the Joule effect and voltage drops, the total losses of the installation are:

$$K_T = [1 - (K_R + K_X)] = [1 - (0{,}1 + 0{,}1)] = 0{,}8 \qquad \textbf{(Eq. 7.23)}$$

The total energy consumption considering the losses is of:

$$\mathrm{C'_{req}} = \frac{\mathrm{C_{req}}}{K_T} = \frac{8916{,}081 \frac{Wh}{day}}{0{,}8} = 11145{,}102 \frac{Wh}{day} \qquad \textbf{(Eq. 7.24)}$$

The total energy consumption can also be expressed as follows:

$$\mathrm{C'_{req}} = \frac{\mathrm{C'_{req}}}{V_{nom}} = \frac{11145{,}102 \frac{Wh}{day}}{120} = 92{,}876 \frac{Wh}{day} \qquad \textbf{(Eq. 7.25)}$$

The polycrystalline module considered for the sizing and which was subsequently installed, is the model J-M-250W from Panasonic. The technical characteristics of the module are:

Table 7.5: Solar panel specifications

Model	J-M-250W
Peak Power (Pmax)	250 W
Voltage (Vmp)	36 V
Current (Imp)	6,95 A

Open circuit Voltage (Voc)	43 V
Short circuit current (Isc)	7,26 A
Dimensions of module (mm)	1650 x 991 x 50
Efficiency (%)	90

Considering (V_{mp}), (I_{mp}) and (η) of the panel chosen for this sizing, and considering ($V_{nom} = 120\ V$); Equations Eq 4.12, Eq.4.13, Eq. 4.14, Eq. 4.15, are applied to obtain the following results:

$$E_{panel} = 0{,}9 \cdot 6{,}95\ A \cdot 5{,}79\ h = 36{,}214\ Ah \qquad \textbf{(Eq. 7.26)}$$

$$n_{pp} = \frac{C'_{req}}{E_{module}} = 2{,}565\ \approx 3\ panels \qquad \textbf{(Eq. 7.27)}$$

$$n_{sp} = \frac{V_{nom}}{V_{mp}} = 3{,}333 \approx 3\ panles \qquad \textbf{(Eq. 7.28)}$$

$$N_{total} = n_{sp} \cdot n_{pp} = 3 \cdot 3 = 9\ panels \qquad \textbf{(Eq. 7.29)}$$

Multiplying the number of modules in parallel by the number of modules in series, you get that the total number of modules required is 9. The installed power of panels is thus 2250 W (9 modules of 250Wp). It should be noted that, for the panels in series, it was preferred to round down the resulting value to avoid oversizing the system even more than needed. Energy more than needed would be generated with 12 modules of 250 W (3 in parallel and 4 in series). The system will have a nominal voltage of 108 V (3 panels of 250W, connected in series). As the pump works properly within 30V and 300V, 108V is an acceptable value.

Once the installation was completed and during the testing days of the electrical system, it was observed that the voltage generated by the panels fluctuated between 90 and 130 V, due to the variation in the intensity of the sun and the tolerance of the solar panels. In periods where the voltage exceeded 120 V, according to the manufacturer, the controller works more efficiently. In periods where the voltage is less than 120V, the controller and especially the pump work perfectly since the voltage is within the range of 30V to 300V, required by the pump.

The maximum output current of the panels is 20.85 A (3 panels in parallel, Imp = 6.95). The value of the nominal consumable current by the pump is 8.4 A. With a connection of 8 panels (2 in parallel and 4 in series; 2000 Wp) the maximum current and the maximum voltage deliverable by the panels are 13.9 A and 144V, respectively. With this maximum current the pump would have been able to work correctly, but we have decided to connect 9 panels so that the maximum current can be higher for two main reasons. Firstly, the system must be able to perform in the eventuality of pump failure and that another pump with a higher current requirement than the previous pump must be purchased or in the event that another useful electrical device has to be plugged into the plant. Secondly, since the grid is not reliable in the locality, it could be considered to install a charging system of devices (mobile, mp3) that would help to exploit even more of the energy generated.

7.3.2. Description of the controller

For this system, the pump those not need an inverter because it works in DC and the power generated by the solar panels is in DC. The pump can be powered directly from the panels, but an element of management and control is necessary in this system to synchronize more efficiently the panels, the pump and the amount of water in the tanks.

The chosen control unit is the CU 200 SQFlex. It has maximum point monitoring and it's suitable for water supply systems based on renewable energy (solar and wind). It is in charge of control and communication for the SQFlex pump system. It enables connection of a level switch placed in a water tank which acts as a pump cut-out function when the water tank is full. The CU 200 offers system monitoring, it indicates when the reservoir is full, pump operation, input power. The control unit also offers alarm indication, it indicates operational stoppage in case of dry running (low level of water in the borehole, so the pump is about to emerge), insufficient energy supply, no contact to pump, overvoltage, overtemperature and overload.

The communication between the control unit and the pump takes place through the power supply cable, so no extra cable is required.

The following table lists the properties of the control unit:

Table 7.6: Properties of the control unit (CU 200 SQFLEX)

Model number:	CU 200
Power consumption:	5 W
Rated voltaje:	30-300 VDC or 90-240VAC at 50/60 Hz
Max. load	100 mA
Back-up fuse	10 A
Weight:	2 kg
Dimensions:	185 mm X 232 mm X 92 mm

7.3.3. System's electric protections

The Control and security connection can be seen in Fig.7.5. The parts of which are the following:

- **A: Lightning arrester**
- **B: Circuit breaker (automatic switch) and DC voltmeter**
- **C: Control unit CU 200 SQFlex**
- **D: Cables from the solar field**
- **E: Cable connecting the controller to the water pump**
- **F: Cable connecting the control and the float (water level sensor in the tanks)**

The cables from the solar fields (positive, negative and ground terminals) contain the generated energy. These cables are firstly connected to the lightning arrester. The lightning arrester is connected to the ground (inserted 1.2 m below ground). The lightning arrester then sends the electricity to the case containing the circuit-breaker and the DC voltmeter. The electricity then goes to the controller, which uses it to perform its functions in the system. The controller is responsible of controlling and sending part of the energy to the pump through the cable indicated with the letter E. The controller also controls the water level by an electric sensor connected to it through the cable indicated by the letter F.

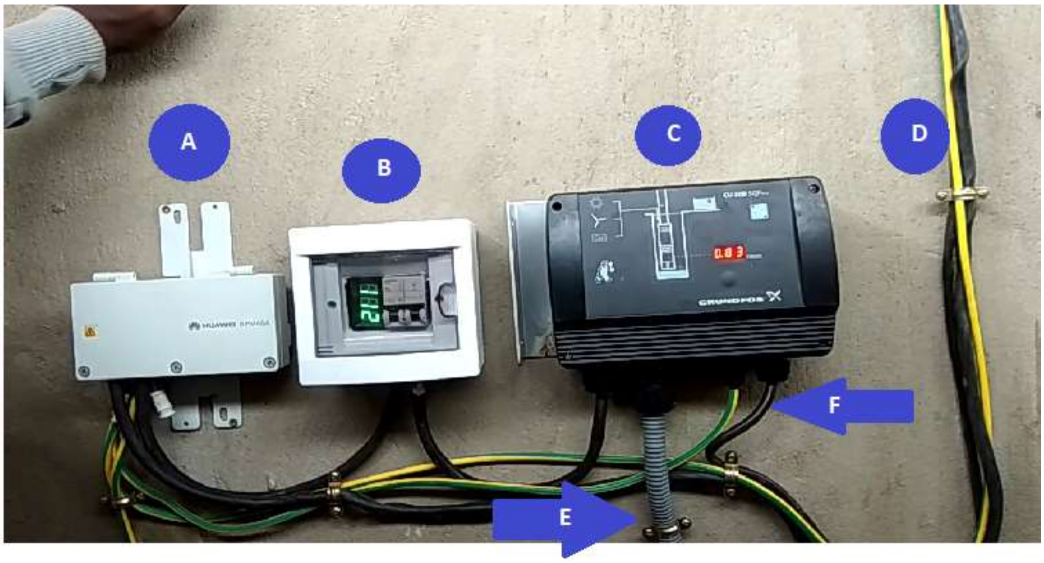

Figure 7.5: Connection of the electrical system. Source: Own Picture

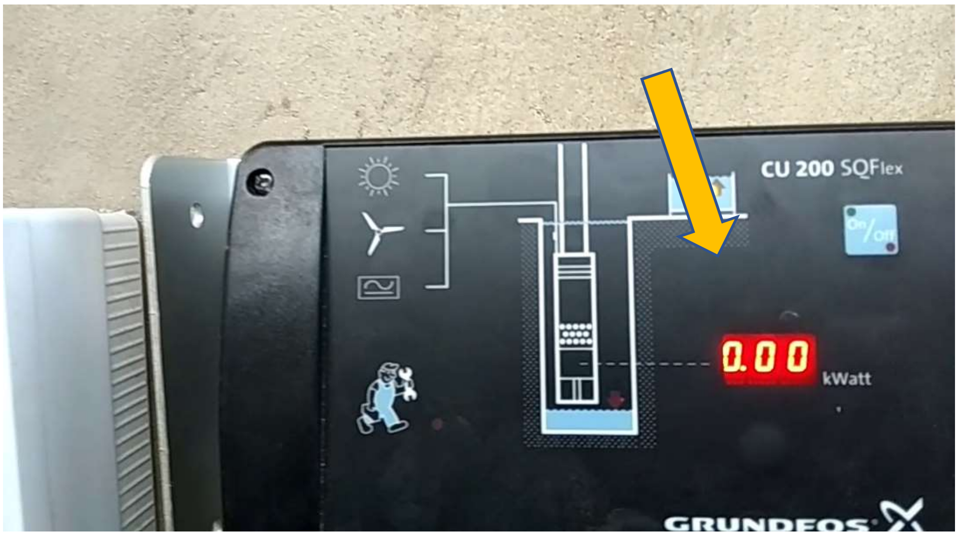

Figure 7.6: Orange arrow, the controller's indicator informs that the water tanks are full. Source: (Own Picture)

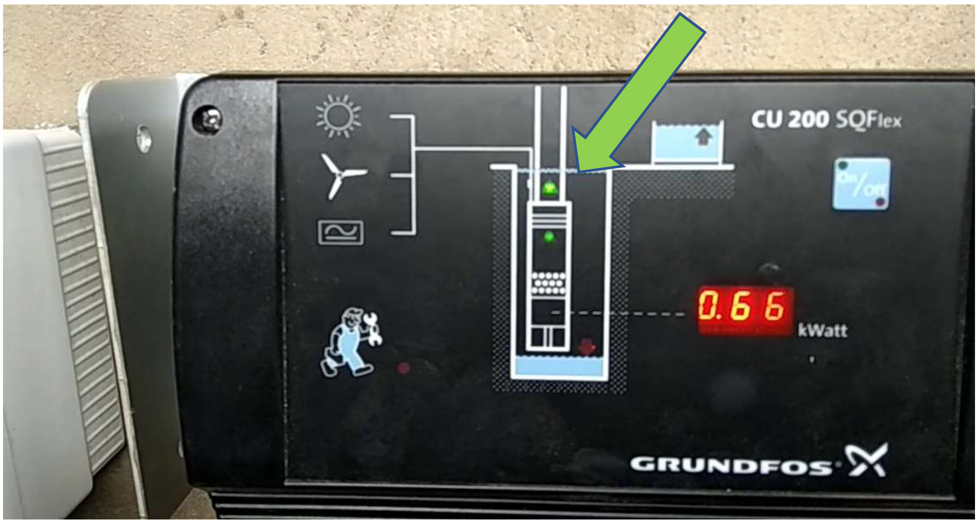

Figure 7.7: Green Arrow, the controller's indicator informs the pump is pumping water (The power of the pump at this moment is 0,66 kW). Source: Own Picture

Figure 7.8: Red Arrow, the controller's indicator informs the pump is no more pumping to avoid dry running as there is not enough water in the bozehole. Source: Own Picture

7.4. Other design considerations (Possible improvements or future improvements)

7.4.1. Hybrid system

In order to reduce dependence from the sun and reduce the risks of system stoppage, the possibility of increasing the energy sources to feed the pump can be examined, thus making a hybrid system. Several technologies could be chosen, but the one considered in this work is a connection of the solar system with the grid.

Connecting to the grid would be a good way to ensure that the system will always work. In times of solar power failure, the grid would provide the power required to run the pump. The correct synchronization and optimization of the grid - solar photovoltaic could lead to the following:

- Increase the daily pumping hours by decreasing the extraction flow (A lower power pump would be chosen).
- Reduce the size of the water tank
- Decrease the installed power of solar panels

In the locality where the project has been carried out, the connection to the network is not easy to implement because of the complications due to the location of the installation. The implementation of this hybrid system means an increase in material and installation costs. At the same time, the electricity network in Banekane is not reliable, as electricity blackouts often occur. The voltage coming from the grid is not stable. The common voltage in Cameroon is 220 V, but in some instants, this voltage can reach 250 V. This phenomenon is responsible for damage to household appliances and other electrical equipment.

The incorporation of an alternative back-up system running on conventional energy sources would help in times when the photovoltaic system is not sufficient or fails. The installation costs are not very high, but the disadvantages are the costs of fuel and maintenance of the generator set. In addition, fuel-powered generators are often noisy and pollute the environment.

The measures taken to deal with the lack of energy is the storage of water. When sizing, several factors of safety and autonomy of the system have been taken into account, increasing the water capacity to prevent any shortage. The stored water is considered as stored energy.

7.4.2. Battery implementation

The implementation of an electrical energy storage system would be a way to prolong the hours of operation of the installation. In periods of overproduction of energy by the solar photovoltaic system, excess energy is stored in the batteries and this energy can be used for later consumptions. It must be remembered that the system designed for this project is an isolated system in which the only source of energy used to power the pump is photovoltaic solar energy and there is no energy from the grid or another back-up system in case of failure. The batteries would also have the role of Back-up system for the system.

Incorporating batteries would imply oversizing the photovoltaic solar system by increasing the nominal power (adding panels and using a solar pumping controller with a higher power). As an additional component a charge regulator would be incorporated and that will be in charge of converting the voltage in DC from the panels to charge the batteries at a lower voltage and in the periods where the batteries are running, it will convert the voltage in DC from the batteries to a higher voltage in DC to feed the pump.

All these measures involve an economic factor, there are several battery technologies applicable to systems similar to this project, but in the end the batteries in any solar photovoltaic system represent a significant weight in the investment in installation materials (the batteries could cost more than 50% of the cost of the other components of the system). It is also very important to take into account the maintenance costs of the batteries to prolong their useful life, although this will depend on the type of batteries installed. In sealed deep cycle lead-acid batteries, water levels should be checked periodically, and terminals should be kept clean. The chemicals in these batteries are dangerous and corrosive, and care must be taken when handling them. Lithium-ion batteries are easier to maintain, but they are much more expensive.

7.4.3. Security of the facility

In order to ensure the safety of the installation, i.e. to protect the pump, the tanks, the panels and the controller against any act of vandalism or theft, a two-storey enclosed building has been constructed.

The first floor is at a height of 1.4 meters and is accessed through a door and using a staircase. On this floor will be placed the two water tanks, the controller and the electrical protections devices. The controller will be located in a separate, enclosed and easily accessible room.

The second floor is at an altitude of 4 m. The panels have been installed on this floor. The only way to access this plant is by using a ladder.

To restrict access to the pump, a small cabin made with reinforced-concrete and an embedded door has been built. It is also planned to install a solar lamp to illuminate the installation at night.

8. Costs-benefit and economic feasibility study

8.1. Introduction

The economic study of the installation is of vital importance to know the viability of the project, for it has been estimated by calculating the investment and the payback period. The study of the economic return has been carried out estimating that the system works in a hypothetical case with fossil fuel.

8.2. Inversion costs

The investment is given by the expenses of the construction of the installation, the displacement expenses and by the engineering work carried out.

This budget is not the official budget of this project since some extra costs appear. This budget is made for academic purposes for this document, the official budget of the project will be delivered to the municipality of Terrassa at the end of the year 2019.

The location in which it is intended to do the installation, being an area away from large cities, involves an increase in cost in materials and workers due to travel. In addition, all equipment imported from other countries such as the pump or the panels have a high cost due to the high customs in Cameroon.

Table 8.1: Drilling costs

Concept	**Units**	**Unit Cost(FCFA)**	**Total cost (FCFA)**	**Total cost (€)**
Bringing in and out of equipment and staff	1	200000	200000	304,80
Drilling of alteration lands in 8" 1/2 to 10".	1	1650000	1650000	2515,41
Installation and arrangement of a temporary PVC casing	1	400000	400000	609,80
MFT soil drilling in 6"1/2 and 6"3/4	1	800000	800000	1219,60
Supply and installation of solid PVC pipes 112-125	1	650000	650000	990,92
Supply and installation of solid PVC pipes 112-	1	300000	300000	457,35
Supply and installation of a gravel pack	1	250000	250000	381,12
Supply and installation of everything coming	1	30000	30000	45,74
Supply and installation of a plug	1	20000	20000	30,49

Cleaning and development with air lift	1	500000	500000	762,25
Pumping test	1	350000	350000	533,57
Physico-chemical analysis	1	250000	250000	381,12
Water pretreatment	1	150000	150000	228,67
Drilling head arrangements	1	100000	100000	152,45
Discount			-100000	-1524,5
Total			**4650000**	**7088,88**

Table 8.2: Construction costs

Concept	**Units**	**Unit cost (FCFA)**	**Total cost (FCFA)**	**Total cost (€)**
Singer installation	1	100000	100000	152,45
Stripping of topsoil including any suggestions	1	50000	50000	76,22
Excavation in gutter	4,32 m^3	2500	10800	16,46
Well excavations	10,37 m^3	3000	31110	47,43
Concrete of property	0,03 m^3	70000	2100	3,20
Reinforced concrete	1,8 m^3	150000	270000	411,61
Reinforced concrete	0,31 m^3	150000	46500	70,89
Reinforced concrete	1,26 m^3	150000	189000	288,13
8cm thick paving slab	2,46 m^3	100000	246000	375,02
Concrete staircase	0,98 m^3	120000	117600	179,28
Dallen to double	3,6 m^3	150000	540000	823,22
Elevation	57,6 m^2	4500	259200	395,15
Reinforced concrete	0,41 m^3	145000	59450	90,63
Upper slab	3,6 m^3	145000	522000	795,78
Vertical plasters	54 m^2	3000	162000	246,97
Tiling	18 m^2	5000	90000	137,20
Grid	18 m^2	8500	153000	233,25
Endorsement	1	1000000	1000000	1.524,49

Doors 0.8*2.00	2	40000	80000	121,96
Water tanks	2	500000	1000000	1.524,49
Discount			-100000	-1524,5
Total			**3928760**	**5.989,85**

Table 8.3: Photovoltaic system costs

Concept	**Units**	**Unit Coste (FCFA)**	**Total cost (FCFA)**	**Total cost (€)**
Solar Pump + controller + float	1	3100000	3100000	4.725,92
Solar Panels (PANASONIC)	9	137500	1237500	1.886,56
Grounding Kit	1	1500000	1500000	2.286,74
Accessory	1	200000	200000	304,90
Descuento			-100000	-1.524,5
Total			**5037500**	**7.679,61**

Table 8.4: Travelling expenses

Concept	**Cost (€)**
Airplane tickets	1.341,28
Maintenance	900
Visas	120
vaccinations	67,57
Other	60
Total	**2.488,85**

Table 8.5: Engineering costs

Concept	Time (h)	Price/hour (€/h)	Total Cost
Pre-work	350	25	8.750
Fieldwork	400	35	1.4000
Writing	120	20	2400
Total			**2.5150**

Table 8.6: Total costs of the project

Concept	Total Cost (€)
Groundwater prospecting study	1.219,59
Drilling	7.088,88
Construction	5.989,85
Photovoltaic System	7679,61
Travel expenses	2.488,85
Land costs (300m2)	9.100
Awareness raising	200
Engineering costs	25.150
Other	500
Total	**59416,78**

8.5. Cost-benefit study of the system and payback time

In this section we want to know if the implementation of a water pumping system using photovoltaic solar energy for drinking water consumption of the population of Banekane is a good investment. In this section we will compare in an economic way the use of photovoltaic panels or a system with diesel generator. Common expenses such as the pump will not be taken into account since it affects both in the same way and the savings attributed to the use of fossil fuel will be considered as profits to recover the investment of the photovoltaic system. A price of 0.96€ per litre (average price of gasoline in Cameroon in 2019) will be considered as the price of fuel in this study.

In order to compare both systems, the difference between both investments has been taken as the initial investment:

$$Initial\ investment = Inv_{PV} - Inv_{fuel} \quad \textbf{(Eq.8.122)}$$

Concept	**Value**
Cost of the photovoltaic system (Panels and accessories)	4.478,20€
Cost of gasoline generator system	1.200€
Lifetime photovoltaic panel	20 años
Hours of operation	5
Lifetime gas generator	10 años
Petrol price	0,96 €/l
Annual Fuel Filling Cost	122,25€

The results obtained after applying the previous considerations are as follows:

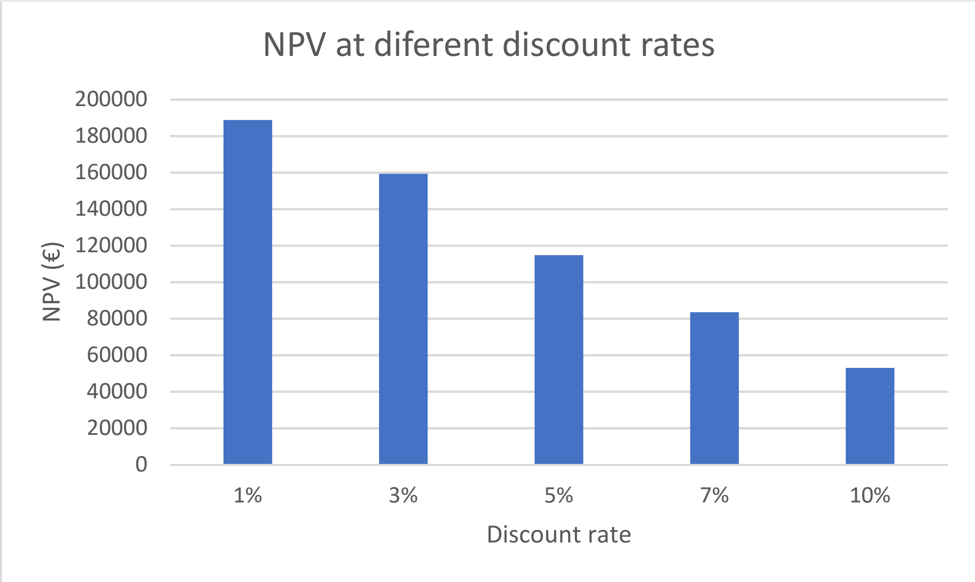

Figure 8.1: NPV at different discount rates

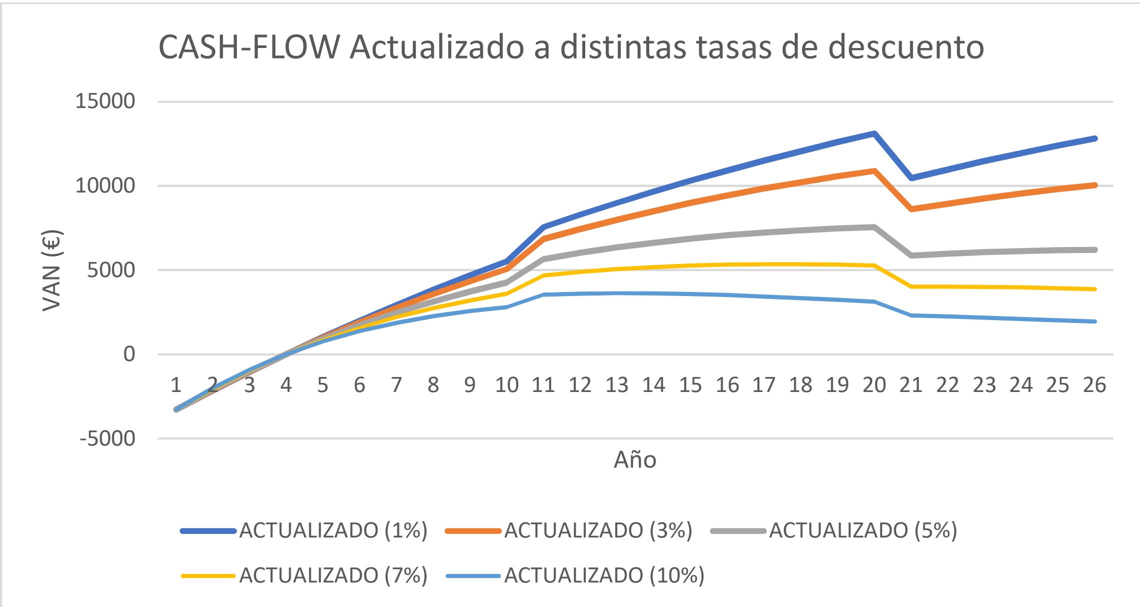

Figure 8.2: Cash-flow at different discount rates

As can be seen, a positive NPV is obtained, which indicates that the investment is recoverable. In addition, the payback period is almost 4 years.

It can be concluded that the installation of photovoltaic panels is more profitable than a gasoline generator bearing in mind that it can have a useful life of 20 years and implies great economic savings.

9. Fieldwork

The following section will describe the activities carried out throughout this project, from conception, preparation and execution.

During the construction of this project, it has been necessary to consult several different experts related to this project. Firstly, attempts have been made to obtain information from professors from the University in order to verify the technical and economic viability of this project. Secondly, we have attended preparatory courses in order to understand the different important aspects of an international humanitarian and social project. Thirdly, we have looked for possible ways to obtain funding (applying to public calls, talking to private institutions and individuals, finding out the existence of some support from the university, crowdfunding). A number of procedures have then been followed in order to be able to raise the funding.

All these previous steps have been necessary to finally be able to travel to Cameroon to be able to implement and finalize the project.

9.1. Fundraising

Undoubtedly the most important and complicated part of this work has been the search and obtaining of the economic resources to start the project. To this end, various public and private entities have been contacted and convinced of the importance, technical feasibility and social impact that the project has and will have.

9.1.1. Provalores NGO

The NGO Provalores, is an entity dedicated to international cooperation between Spain and countries in South America and sub-Saharan Africa to improve the quality of life of children. This NGO started in Colombia in 1999 and was registered in Terrassa, Catalonia in 2000. Provalores mostly works in Colombia to improve the lives of abandoned, abused, marginalized, orphaned children... Some of the projects it has carried out are the equipping of a home for abandoned children in Cota (Cundinamarca) and the reform of the Cajica Day Centre. In Terrassa, Provalores annually organizes talks, solidarity meals and other cultural activities.

NGO Provalores and its president, Mr. Pablo Ortega Calaf, was the first entity contacted to propose the idea of carrying out this humanitarian work focused on health and development. The NGO has offered to support and advise us with all the documentation that we have had to conceive to be able to apply for different public calls for the financing of social cooperation projects of international cooperation.

Ilustración X: Logo ONG Provalores

9.1.2. Terrassa City Hall

The City Council of Terrassa opens annual calls in the field of international cooperation so that projects of local entities can find the necessary funding to carry out their initiatives. These projects are evaluated by the municipal council of Solidarity and international cooperation and all the the best ones are subsidized.

It is important to mention that this project has been presented in the municipality of Terrassa and has obtained the sixth best score among the 29 participants. Taking into account that this project has stood out among many other projects that have years of experience and are carried out by many professionals in the sector, it can be said that this project has good foundations and a high probability of success.

Ilustración X: Logo Ayuntamiento de Terrassa

9.1.3. Main Memory

Main Memory is a company that provides software, platform and infrastructure as a service, as well as cybersecurity coverage. Annually this company collaborates with cooperation projects for the good of children.

Main Memory has participated in one of the hardest tests for a cyclist, the Titan Desert 2019. Main Memory has decided that for every kilometre travelled by the cycling team in this great event, the company would make a donation to the GEWW project.

Ilustración X: Prueba Titan Desert 2019

Ilustración X: Logo Main Memory

9.1.4. Centre for Development Cooperation (CCD-UPC)

The Centre for Development Cooperation is an entity of the Polytechnic University of Catalonia (UPC) that coordinates development cooperation programmes and participation in the social volunteering of the UPC. Part of the contributions made by this unit are thanks to the 0.7% campaign. This campaign allows students to make a voluntary contribution through tuition. The university staff can also contribute through their payroll.

Ilustración X: Logo Campaña 0,7%

9.1.5. Farmacia del mercat

La *farmacia del mercat* is a pharmacy located next to the Municipal Market of Rubí. It is committed to people's health and solidarity projects.

Ilustración X: Logo Farmacia del mercat

9.1.6. Crowdfunding

Migranodearena is a social and solidarity crowdfunding platform that acts for social causes through the creation of solidarity challenges based on collective financing. Through migranodearena.org you can support NGOs, third social sector entities, cooperatives and non-profit organizations such as foundations or associations.

9.2. Awareness-raising in Cataluña

One of the aims of this project has also been to raise awareness in Catalonia about the importance of drinking water and its scarcity in various parts of the world. To this end, a series of speeches have been given by secondary school students.

These speeches have presented the situation of drinking water in the world and the difficulties people face in various parts of the world to obtain it, contrasting the situation that people in these places and those in developed countries experience. Allusions were made about the social and health issues originated due to their lack. A message was launched to encourage responsible consumption in everyday life. These students have also been encouraged to value and continue training academically in order to reach their goals.

9.3. Dissemination and advertising

The visibility of the project has been a very important factor in reaching out many people for them to understand the situation which exists in other parts of the world and also for them to voluntarily support and contribute. For this reason, profiles have been created on social networks (Facebook, Instagram, LinkedIn) and a website has been built to give visibility to the project. A proper name was given and a logo was created to give personality to the project. A descriptive video has also been recorded to show the faces behind the project.

9.3.1. Webpage

The website has been created by Kwabena Anokye Amofa, a student of chemical engineering at the UPC. The page served as a means of informing about the different tasks that would be performed throughout this project. The administrator has used images, pictograms and explanatory texts to reach out to the visitors of the page.

It was also used to inform about the main participants and collaborating entities in this project. The website was also used to attract sponsors and donors by redirecting them to the crowdfunding platform.

Web link: www.gewwproject.com

9.3.2. Social Media

The Facebook and Instagram social network profiles were created by Laia Bou March, an energy engineering student at the UPC. Through these profiles the administrator has uploaded images and short texts to inform followers about the evolution of the project. The descriptive video of the project was made by Abril Casals. The participants of the GEWW project took part in the video.

UPC students:

- Laia Bou March (Energy Engineering)
- Kwabena Anokye Amofa (Chemical Engineering)
- Sergi Ortega Ruiz (Mechanical Engineering and Energy Engineering)
- Darcel Aurel Yoya Tchaptchet (Energy Engineering)

Université des Montagnes student:

- Venant (Degree in renewable energies)

Research tutor:

- Herminio Martínez García

Profile link Instagram:

- https://instagram.com/gewwproject?utm_source=ig_profile_share&igshid=19ytshg8sui0c

Facebook profile link:

- https://www.facebook.com/gewwproject/?epa=SEARCH_BOX

9.4. The creation of a renewable energy association at EEBE Campus

One of the initial objectives of this Project was the creation of a student association within the university campus. We do not want this initiative to end with the students currently participating, but rather that more students of the Energy degree can be part of it to contribute to their academic and professional training helping people.

The main objectives of this association would be to carry out an international cooperation project on an annual basis. These projects should arise of initiatives specific to the destinations where the projects will be carried out, since that local people have a better understanding of the problems of which need some primordial solution.

On the other hand, there will always be an attempt to promote the use of renewable energies such as photovoltaic, wind or thermosolar. It will also be important to promote gender equality in our projects. Finally, it will be of vital importance to create social systems and have a firm support of the counterpart to ensure the sustainability of projects over the years.

This initiative has been very important to us from the beginning. With the GEWW project, several aspects have been identified on which to reflect and prepare in more depth. In order to realize projects of international character it is not only important to get the investment but it is capital to be ready to what can be found outside your comfort zone. Language, cultural clashes, time, internal organization, teamwork, counterpart, among other aspects are important to assess before throwing yourself into the water.

Going to Cameroon to carry out this project has been an enriching experience culturally and above all professionally, but in the process of obtaining funding, there have been several complications, since public and private entities and individuals do not finance projects easily and less if the applicants are unknown on to them.

Creating an association takes a lot of responsibility, time and sacrifice. Apart from the aspects mentioned above, it is important to mention that as everyone is finishing their degree, it will be very complicated to be involved with the university in the management of the association.

If the association we want to create has as goal realizing international projects, these may be quite expensive and it will be better to focus on more local issues.

10. Local impact of the project

In this section we will focus on the impact that the project will have at an environmental and social level in the communities of Banekane, Bangangté, Terrassa, Barcelona...

10.1. Environmental impact analysis

Regarding the environmental impact, not using fossil fuels to use photovoltaic panels to supply energy to the pump implies a decrease in the emission of greenhouse gases into the atmosphere.

To determine the amount of greenhouse gas not emitted into the environment, we can make an estimation assuming that the system uses gasoline instead of photovoltaic energy.

Taking as data:

- Calorific value of gasoline: 35.475 KJ/l
- CO2 emitted to the atmosphere per litre consumed: 2.2 kg
- Performance of a gasoline generator: 30%.
- Energy consumed by the pump: 8.106 Wh = 29181,6 KJ

Therefore, the mass of CO2 emitted into the atmosphere in one day:

$$\frac{29181{,}6\ kJ\ \cdot 2{,}2\frac{kg}{l}}{0{,}3\ \cdot 35{,}475\frac{kJ}{l}} = 6{,}03\frac{kg\ CO_2}{day} \qquad \textbf{(Eq.9.1)}$$

In one year:

$$\frac{365\ days}{1\ year} \cdot 6{,}03\frac{kg\ CO_2}{day} = 2.201{,}8\frac{kg\ CO_2}{year} \qquad \textbf{(Eq.23)}$$

In addition, the use of clean energy has been promoted and its use has been encouraged. For this reason, the different Cameroonian and Catalan university students who have worked on this project will have more knowledge on the field and will preferably apply clean technologies rather than the use of fossil fuels.

10.2. Social impact analysis

The use of good quality drinking water leads to an improvement in the general wellbeing of the local population and a reduction of illnesses as mentioned above. All children who can attend school because they have less household duties transporting and treating water, will mean a long-term improvement in Banekane.

In addition, there has been a task of raising public awareness about the problem of water in the world and how we can act proactively. It is hoped that this project will be an example for all those who have learned about it through social networks, the talks that have taken place or read this final grade work.

10.3. Sustainability of the project

In order for the objectives set for 15 or 20 years to be truly met, it is necessary to establish mechanisms for the survival of the facility. Two mechanisms have been established.

The first is management by the local population. A management committee will be set up with the support of the Bangangté commune which is there to monitor and supervise the committee. The committee will be formed by village residents, through an assembly of men and another assembly of women of Banekane. Its function will be of daily basis for the equitable distribution of water, monitoring of the installation, managing the transport of water to the public school... The members of the committee will also have to designate and train the people in charge of the maintenance of the building (interior cleaning of the rooms, exterior cleaning, periodic cleaning of the panels. The members of the committee will define the rates and payment terms for drilling water and keep the money collected in a savings account in the name of the committee's representatives. They will organize periodic meetings and manage the funds dedicated to drilling maintenance.

Secondly, there are third party evaluators who will periodically go to the facility to see that it is working properly and that the population is actually benefiting from the well. The third evaluator is the women's association "Les Divas" from Douala.

Furthermore, this project has a budget for possible future repairs of the facility that would be paid between the NGO Provalores and the village of Banekane.

Conclusions

Firstly, the problem has been spotted by informants from Bangangté and an effective solution has been chosen that uses a technology available and developed in the country.

On the other hand, it must be said that the objectives set have been achieved. A reasonable budget has been gathered to carry out the construction of the installation that is already operational. In addition to this, the students responsible for this project have acquired knowledge in: advertising, social networks, subsidies, legal procedures, international experience, economics, negotiations, civil engineering, geology and renewable energy.

Concerning the technical calculations, 9 panels of 250 W have been sized to supply electricity to a 1.4kW pump and possibly a charging station for telephones or similar is forseable. Regarding storage, it has been concluded that the most economical way and that meets the needs of the population are two PVC tanks with 5,000 liters of capacity each.

The construction is big enough to be able to do maintenance comfortably, and it also protects the main electrical equipment.

Finally, awareness-raising activities have been and will still be carried out for the Catalan population in order to raise awareness of the problem of water in the world and care for the environment.

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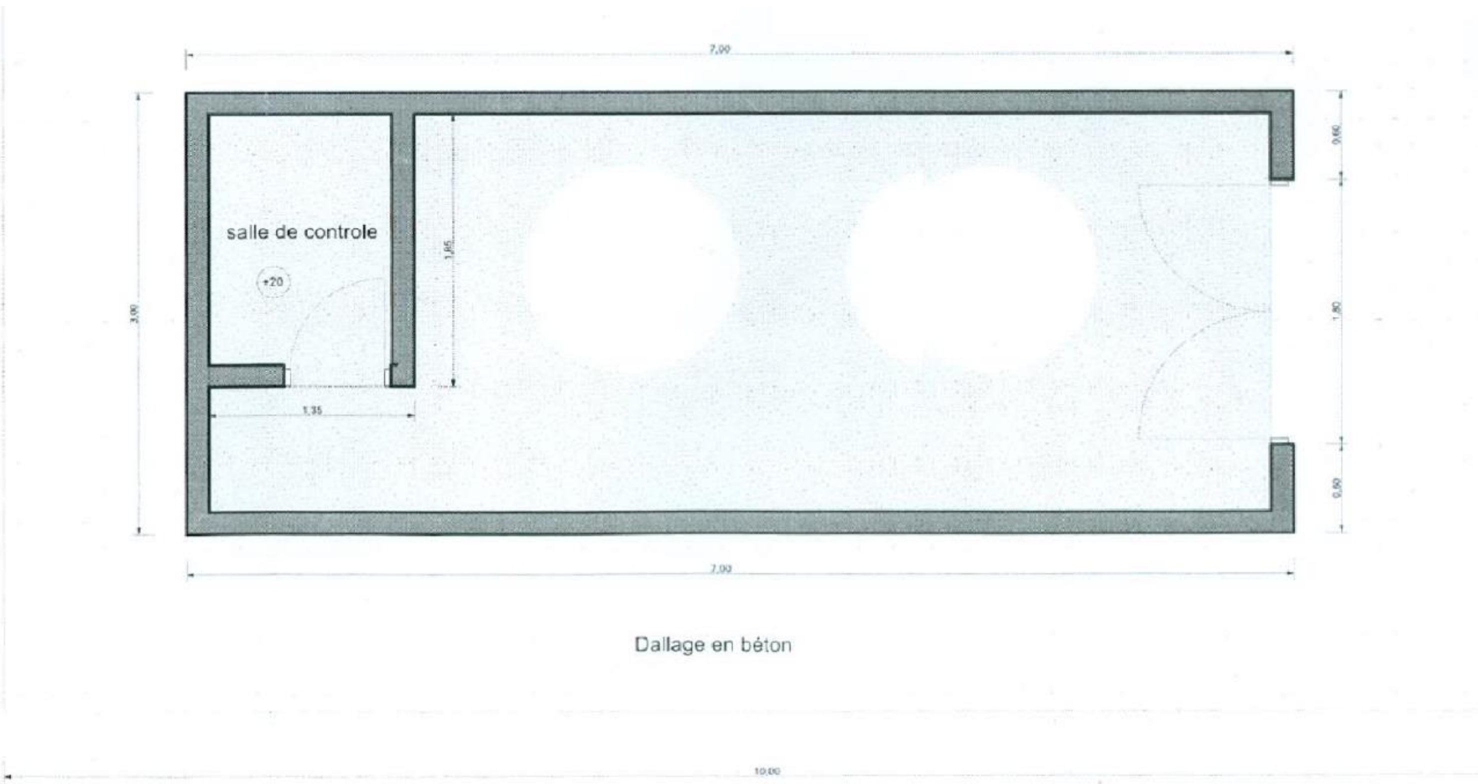
Annexes

Annex A

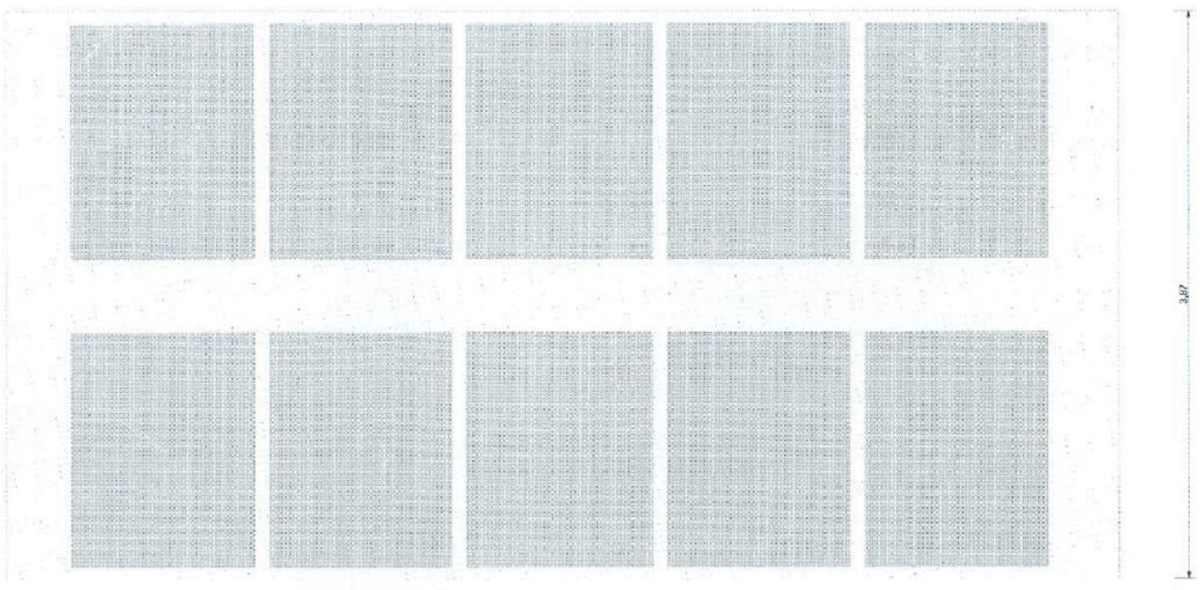
Construction plans

GEWW

Green Energy
Water Well

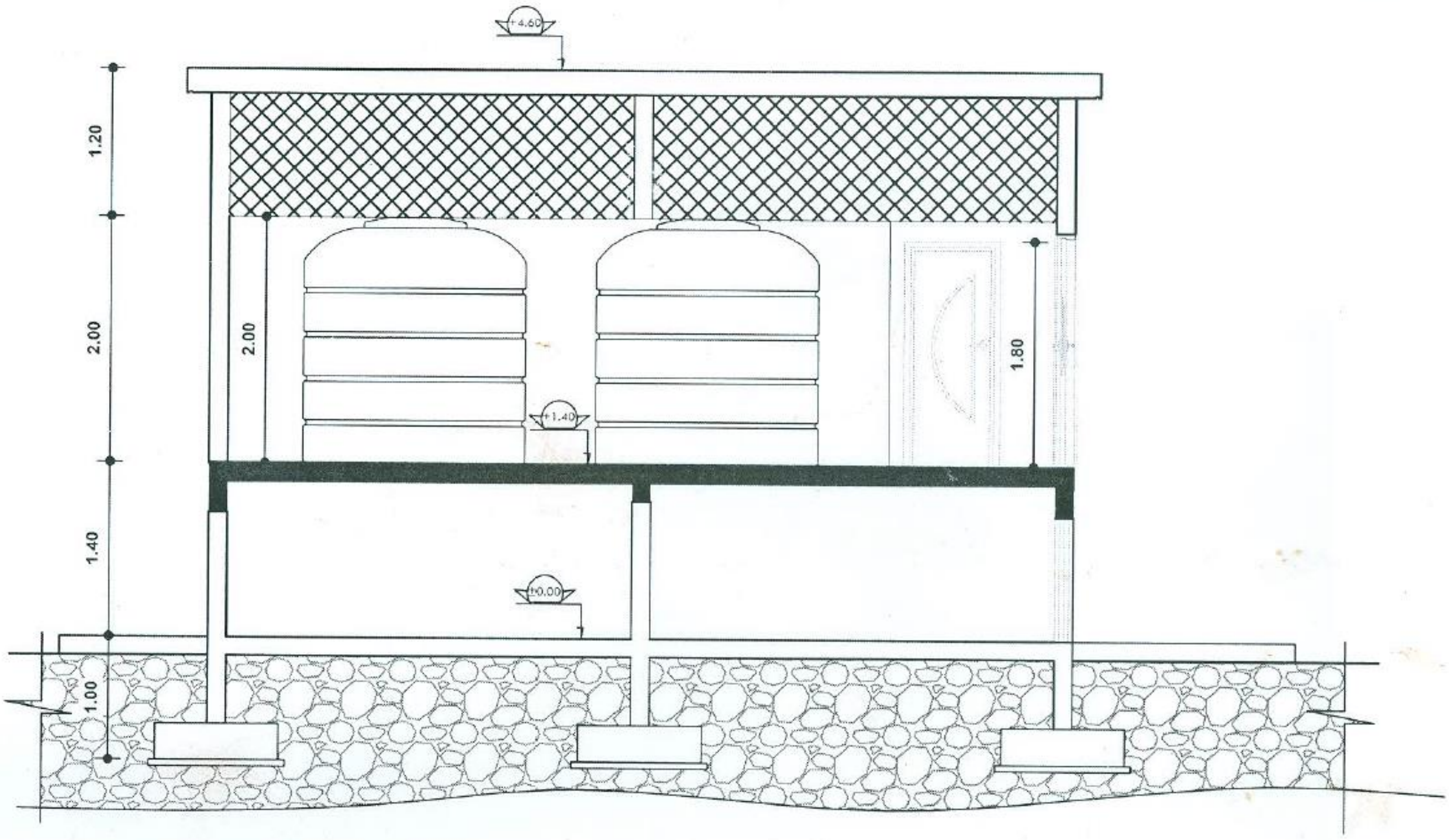


PLAN DE DISTIBUTION CHATATAUX D'EAU

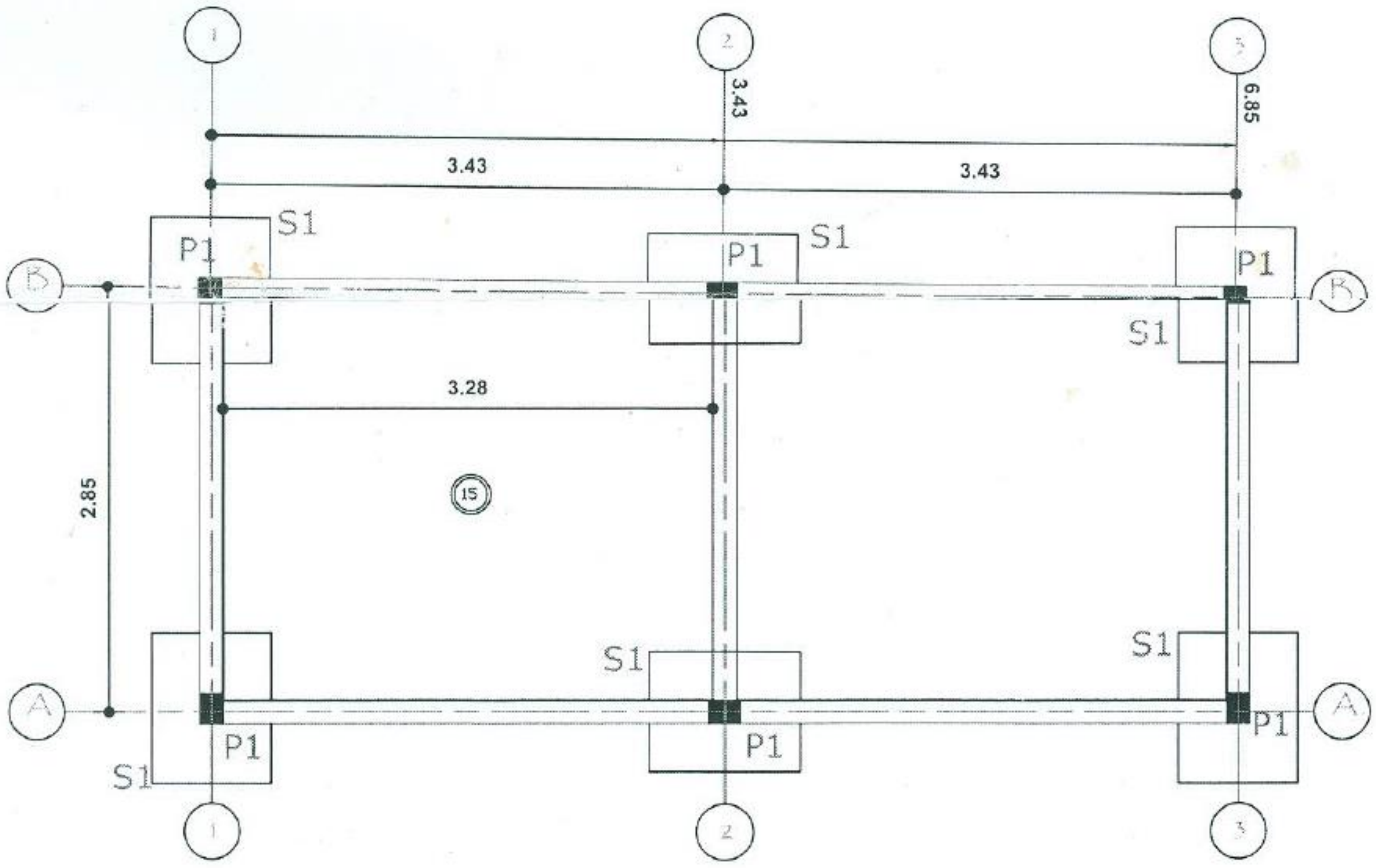


Plan de isposition des panneaux solaire

REPUBLIQUE DU CAMEROUN paix-travail-patrie	PROJET DE CONSTRUTION D'UN CHATEAU D'EAU sis à : Bangangte Maitre d'ouvrage: [illegible]	Conception et etudes	CIS BTP SARL
		Tel:	(+237) 697884711 - 654003864 - 655142942
REPUBLIC OF CAMEROON peace-work-fatherland		DATES	21-08-2019
	PLAN DE DISTRIBUTION	Echelles:	ajuste au format



COUPE LONGITUDINALE



PLAN DE FONDATION

Tableau récapitulatif des poteaux				
nombre	Type	Section (m)	ferraillage	
			filants	cadres et epingles
6	P1	0.15x0.20	4HA12	Ø 6 esp cadres 15cm
Tableau récapitulatif des semelles				
6	S1	0.80X1X0.25	HA10	

CIS BTP Sarl	REPUBLIQUE DU CAMEROUN	PROJET DE CONSTRUTION D'UN CHATEAU D'EAU	conception et étude	CIS BTP SARL
		Maitre d'ouvrage ONG PROVALOKE	contact:	(+237) 655142942 - 652448121 - 697884711
	REPUBLIC OF CAMEROON		DATES	21-08-2019
		- Coupe longitudinale - Plan de Fondation	Echelles :	ajusté au format

Annex B

Hydrogeophysical study report

CIS BTP SARL
ETUDE GEOPHYSIQUE ET HYDROGEOLOGIQUE POU FORAGE email : info@cisbtp.com TEL : 655142942-652448121

PROJET DE REALISATION D'UN FORAGE D'EAU EQUIPE D'UNE POMPE SOLAIRE DANS LA REGION DE L'OUEST -DEPARTEMENT DU NDE -ARRONDISSEMENT DE BANGANGTE – VILLAGE BANEKANE- POUR LE COMPTE DE L'ONG PROVALORES

ETUDES HYDROGEOLOGIQUES ET GEOPHYSIQUES D'IMPLANTATION DE FORAGE

21 Juin 2019

ETUDES HYDROGEOLOGIQUES ET GEOPHYSIQUES D'IMPLANTATION DE FORAGE

Réalisée par l'entreprise CIS BTP SARL
Spécialisé en Hydrogéologie et Géophysique

SOMMAIRE

I - INTRODUCTION

En date du 21/06/2019, nous avons à la demande de L'ONG PROVALORES procédé aux études géophysiques en vue de l'implantation d'un forage dans le village BANEKANE.

Ces études ont porté sur les observations géologiques, morphologiques, hydrogéologiques et sur les mesures géophysiques de confirmation.

Cette zone souffre de l'insuffisance de l'alimentation en eau potable et la population se retournent vers les eaux des puits et forages sans garantie de qualité. Cette étude contribue à établir une relation entre la lithologie, la qualité et la dynamique des eaux souterraines. Les prospections cartographique, hydrologique, hydrogéologique, géo électrique et les implantations.

La mise en évidence de ces structures failles nécessite l'usage de plusieurs techniques complémentaires du fait de leur caractère discontinu et aléatoire.

En plus, les quelques fractures qu'on peut y déceler sont masquées par un important manteau latéritique.

Les techniques géophysiques utilisées dans le cadre de cette prospection ont constitué uniquement à l'appréciation de la susceptibilité magnétique des roches du proche sous-sol. La susceptibilité magnétique est un des paramètres géophysiques des roches qui dépendent beaucoup de leur degré de saturation.

Le but assigné à notre mission était de trouver des zones où le couple altérations-fractures de la roche-mère est suffisamment développé pour favoriser l'accumulation et la circulation des eaux souterraines.
Au terme des différentes investigations menées sur le terrain, deux sites potentiels de forage ont été mis en évidence dans la zone comme nous pouvons le voir sur les photos.

Le présent rapport qui marque la fin de la mission de prospection, rend compte de notre démarche, de nos investigations, de nos conclusions et Recommandations.

Était présent : des membres de L'ONG PROVALORES

II – CADRE PHYSIQUE DU DOMAINE

La zone est située sur un flanc de colline plongeant vers le sud. Le relief à cet endroit est un glacis aux pentes variables. La dénivelée entre le site et le fond de la vallée la plus proche est de l'ordre de 20 m.

III – METHODOLOGIE

La méthodologie mise en œuvre pour la phase géophysique de la prospection est le sondage électrique

Principe de la méthode

La méthode électrique consiste à l'usage des courants continus ou alternatif à très basse fréquence (rendant négligeables les phénomènes d'induction) dans le but de comprendre la structure du sous-sol grâce à l'étude des résistivités électriques des formations qui le composent. La résistivité électrique est un paramètre important en hydrogéologie, car pour la plupart des roches, cette résistivité est de type électrolytique et elles conduisent le courant électrique qu'elles contiennent. Seuls quelques rares gites métallifères se comportent en conducteurs.

Dans la méthode du sondage électrique, on utilise sur le terrain deux électrodes d'émission de courant A et B, ainsi que deux électrodes de mesure de potentiel M et N, si bien qu'entre ces dernières on mesure la différence de potentiel due à l'action de A et B. On recueille des informations géo électriques à la verticale d'un point donné ; en poussant l'investigation toujours plus profondément. Pour cela, on effectue une série de mesure en agrandissant à chaque fois la longueur de ligne d'émission A-B, tout en gardant fixe le centre du dispositif.

En reportant sur un graphe bi logarithmique, les valeurs de résistivités apparentes mesurées en fonction de la longueur de ligne ; on obtient la courbe de sondage électrique ci-dessous.

L'interprétation de cette courbe permet dans les cas favorables (bon contrastes de résistivité et couches épaisses), de déterminer les résistivités vraies et les épaisseurs des différents niveaux rencontrés sous la surface. On obtient un sondage type en effectuant une succession de mesure avec un dispositif d'émission A-B de longueur croissante. A et B sont séparés de manière progressive de part et d'autre des électrodes de potentiel M et N et du point central O (dispositif VERY LOW FREQUENCY)

L'objectif étant de pourvoir, de déterminer les variations verticales du profil des résistivités apparentes des formations géologiques sous –jacentes et d'apprécier leur degré porosité de fracturation ou de fissuration

Interprétation

Elle consiste à donner un contenu géologique et partant hydrogéologique aux diagrammes géo électriques obtenus. Les corrélations avec les observations du terrain, les coupes de forages existants dans la région, permettent de prendre la mesure de la structure. A ces éléments, il convient d'ajouter les paramètres importantes tels que : Le bassin versant, la puissance de la couche des altérites qui joue ici le rôle de réservoir.

IV- MATERIEL MIS EN ŒUVRE

Le matériel mis en œuvre au cours de cette prospection est conforme à la norme VLF (very low frequency)

- Un appareil géo électrique
- 2 bobines de fils
- 2 électrodes non polarisables en cuivre
- Un décamètre
- Une caisse à outil
- Une machette
- Un burin
- Une massette de 2kg
- Une boussole
- Un GPS de navigation
- Un véhicule advensis (pour projet située au bord du goudron)

V – TRAVAUX EFFECTUES

Le premier contact avec le terrain a consisté à :

La recherche des structures et présentant un potentiel hydrogéologique appréciable.
La collecte des données.
La reconnaissance du bassin versant et des structures géologiques.
La recherche des indices hydrogéologique (sources, alignement des grands arbres …)
La réalisation des tests (sondage géo électrique) sur le site.

Une étude de terrain a été effectuée par une synthèse des investigations hydrologiques (observation des sources, puits, cours d'eau, forage existant…) et morphologiques (observation du relief en vue d'évaluer le bassin versant.
La méthode d'étude que nous avons mise en œuvre est la méthode géo électrique, sous son aspect vertical (sondage).

VI – RESULTATS OBTENUS

Hydrogéologie

Nous avons observé dans la zone et aux environs, aucun puits et aucun forage qui peuvent nous permettre de donner un indice hydrogéologique et piézométrique.

Géophysique – implantation

La géophysique indique un sol bien ravitaillé comme nous pouvons le constater sur les graphiques ci-après. La courbe que nous observons nous montre la structure du sol et sa chute comme zone de fracture.

La zone bleue et violette nous montre le passage d'eau. Ainsi nous pouvons donc réaliser un forage avec un pourcentage de succès estimé à 80% avec une Profondeur estimée entre : 80 m – 85 m et d'après notre courbe les numéros 5 et 10 correspondent aux zones de fractures soient 36 et 72 m et un débit estimé entre 1000 litres et 1500 litres par heure.

VII – RESUME

SITES	EPAISSEUR D'ALTERATION	FRACTURE	PROFONDEUR DE FORAGE
F1	Entre 15 et 20 m	Entre 36 et 72 m	Min 80 m max 85m
F2	Entre 20 et 25 m	Entre 40 et 75m	Min 85 m max 90 m

Stratigraphie :

- Epaisseur altération : 15 et 20 m
- Niveaux aquifère : 30- 50 m
- Profondeur estimée : 85 m
- Débit estimé : 1,5 m^3/h

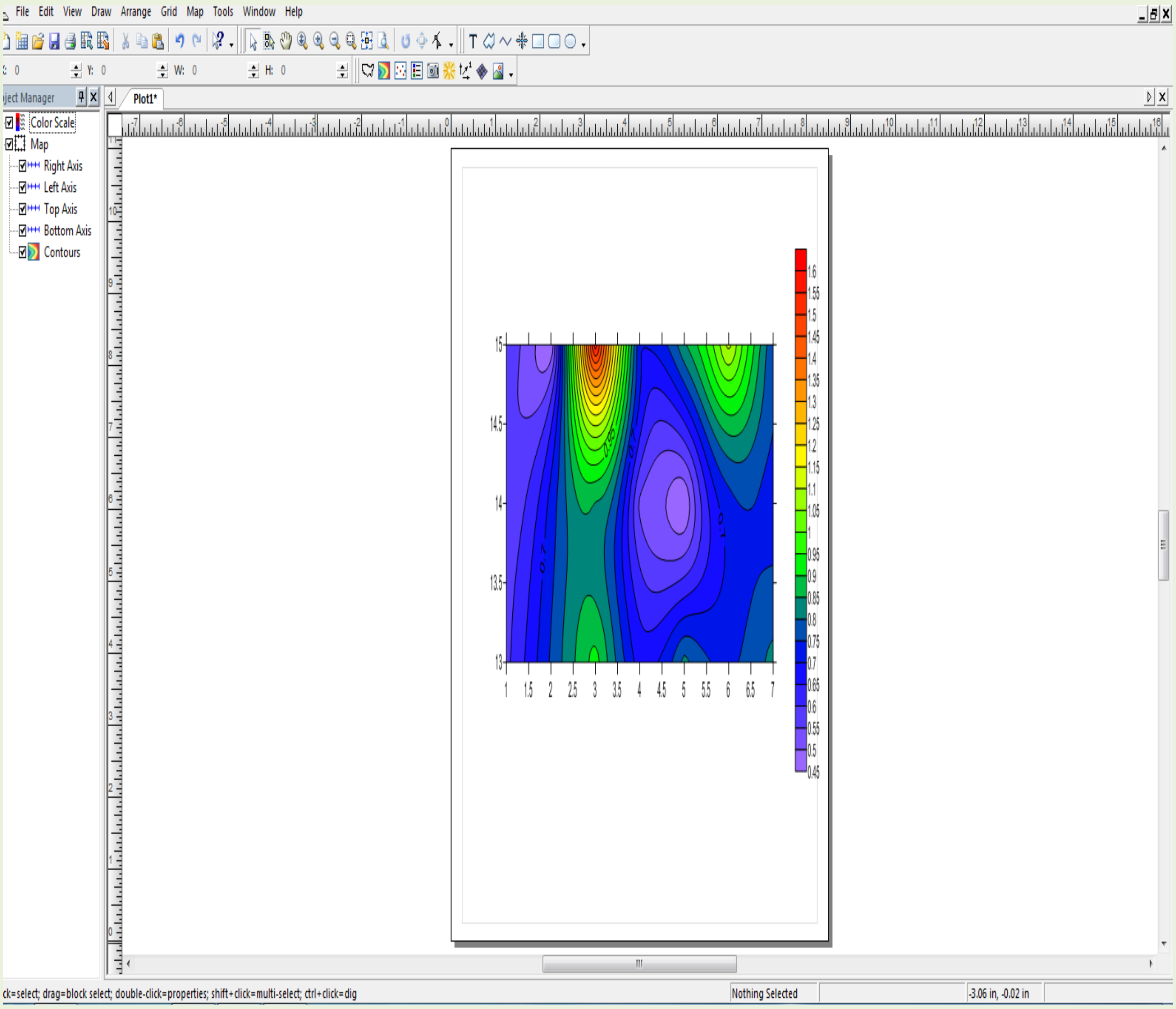
NB : le foreur peut arrêter le forage avant la profondeur estimée s'il juge le débit important.
Accès au chantier facile car proche du goudron (route national numéro 4)

VIII – CONCLUSIONS

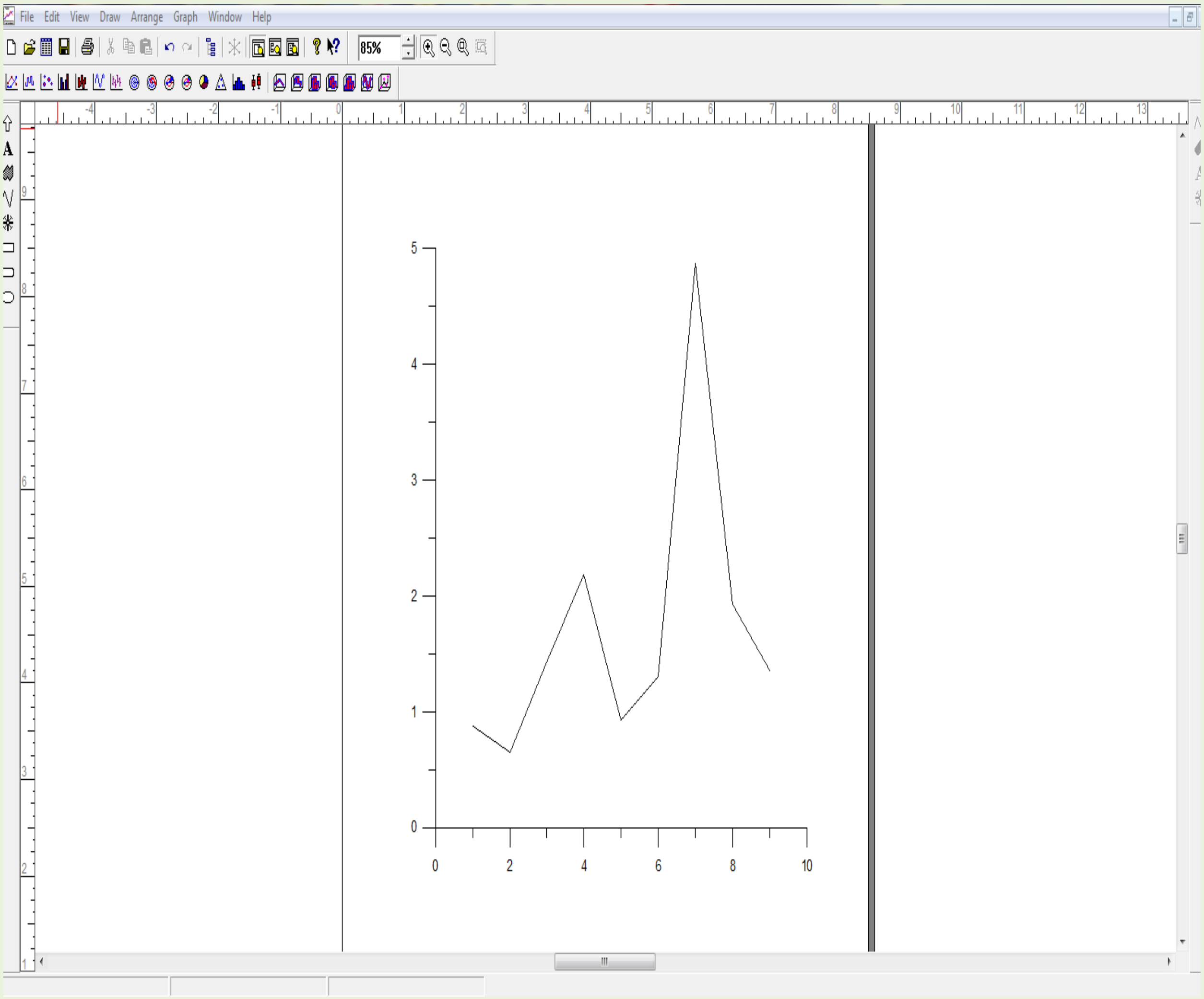
Le but recherché par le client étant la mobilisation de la ressource en eau pour l'exploitation présente et future de son patrimoine, les résultats de nos investigations sont favorables pour une telle démarche.

Une implantation que nous jugeons exploitable selon nos observations et le point favorable est le point situé à 20 m du milieu de la route et à 25,5 m à partir de l'extérieure de la maison comme nous pouvons le voir sur la photo.

Annexes



En effet, le graphe ci-dessus nous montre le passage de l'eau dans la zone. Comme nous pouvons le constater, nous observons une grande zone bleue ; car cette zone montre le passage de l'eau ; ce qui signifie que dans la zone nous avons une grande nappe exploitable. Ceci va être confirmé avec la courbe ci-après.



La courbe ci-dessus nous montre la profondeur du forage et à quel niveau nous allons trouver la nappe phréatique. Ainsi comme nous pouvons l'observer, on constate que la courbe a deux zones de fractures aux numéros 5 et 10 comme qui correspond respectivement à 36 et 72 m de profondeur nous pouvons le voir sur la photo ci-dessous.

Premier Point

Deuxième point d’eau

ETUDES REALISE PAR CIS BTP SARL

Annex C

Drilling report

GEWW

Green Energy
Water Well

REPUBLIQUE DU CAMEROUN

Paix — Travail — Patrie

****

REPUBLIC OF CAMEROON

Peace -Work - Fatherland

****

CIS BTP SARL

Tél : 655 142 942 / 652 448 121

PROJET DE REALISATION D'UN FORAGE D'EAU EQUIPE D'UNE POMPE SOLAIRE DANS LA LOCALITE DE BANEKANE (ENTREE UNIVERSITE DES MONTAGNES), ARRONDISSEMENT DE BANGANGTE, DEPARTEMENT DU NDE, REGION DE L'OUEST

FINANCE PAR L'ONG PROVALORES

RAPPORT DE LA FORATION

L'ENTREPRISE

SOMMAIRE

PREAMBULE

Le **forage** est l'action de creuser un trou (aussi appelé « Puits » dans le domaine de la prospection) dans la Terre. L'équipement du puits, tel les tubages, et de manière générale les moyens techniques permettant de creuser, varient en fonction de son dimensionnement et de ses objectifs. On fore pour prospecter et/ou exploiter le sous-sol. Par exemple, des puits sont forés pour : trouver et exploiter des ressources naturelles enfouies (eau, pétrole, ressources minières) ; la géotechnique ; la géothermie ; l'environnement et la décontamination de sols ; la recherche scientifique pure.

Dans le cadre de l’exécution de notre travail, il est question de faire ressort les grandes lignes de foration qui est une étape importante pour un projet d’adduction d’eau potable.

.

I- LES ETAPES DE LA REALISATION DU FORAGE

La réalisation d'un forage comporte plusieurs étapes comme suit :

- La recherche du point à forer;
- La construction du forage;
- L'équipement du forage;
- Le développement.

I-1 LA RECHERCHE DU POINT D'EAU

Cette recherche est en principe le travail de l'hydrogéologue. Il s'agit d'identifier la présence d'une nappe souterraine le plus près possible au-dessous du lieu d'utilisation et de stockage de l'eau. Le plus simple est de commencer par recueillir les informations et indices disponibles localement en effectuant une visite du site. Elle permettra de faire l'inventaire des puits et forages situés dans les alentours et de mesurer les hauteurs d'eau, d'interroger la population sur la présence d'eau en surface, sur la pérennité de l'alimentation des puits. Des observations sur la topologie et la végétation du site.

I-2 LA CONSTRUCTION D'UN FORAGE

Les forages sont des puits tubés de faible diamètre creusés par un procédé mécanique à moteur (foreuse). C'est un moyen qui est plus rapide et plus économique que la construction d'un puits. Un atelier de forage peut réaliser au moins une centaine de forages dans une année. Construire le même nombre de puits avec une seule équipe de puisatiers nécessiterait plus de 10 ans. Pour la réalisation de notre forage nous avons utilisé deux méthodes, **la méthode rotary** dans les terrains tendres et celle **du marteau fond de trou** dans les terrains durs.

I-3 L'EQUIPEMENT DU FORAGE

Notre forage était prévu pour 85 m d'après les études faites par le géophysicien. Au vue du rapport des études géophysique, nous avons jugé le débit de foration important à 80 m et au regard du changement hydrogéologie du sol, on risquait perdre ce débit. Nous somme alors passé l'équipement du forage, qui est faite d'une colonne de captage. Cette colonne est constituée d'une série de tubes vissés les uns aux autres et servira à soutenir les parois du forage de façon permanente. Au niveau des zones productrices, les éléments de tubage comportent des orifices calibrés (perforations ou fentes) : ce sont les crépines. Et autour de cette colonne nous avons mis du massif filtrant.

Les éléments essentiels constituent l'équipement de forage d'exploitation:

1) **Les tubages pleins,**
2) **Les crépines ou tubages perforés;**
3) **Le massif filtrant.**

I-4 LE DEVELOPPEMENT

Il sert à maximise la productivité du forage et optimiser la capacité de filtration de massif filtrant.

II- CONCLUSION

Le foration est une étape importante pour la réalisation d'une adduction en Eau Potable, elle sert de ressource pour l'alimentation du village, il a été réalisé à un profondeur de 80 m, nous avons obtenu : le toit du socle à 27 m, la première venu d'eau entre 52 m et 67 m et la deuxième venu d'eau entre 76 m et 80 m **(voire annexe)**. Mais le débit exacte du forage ne peu que ce connaitre après essais de pompage du forage.

III- QUELQUES PHOTOS DU CHANTIER

Arrive de la foreuse

Début de la foration

Installation et retrait du tubage provisoire

Equipement du forage

Remplissage du massif filtrant

Soufflage à l'air lift

Replies du materiel

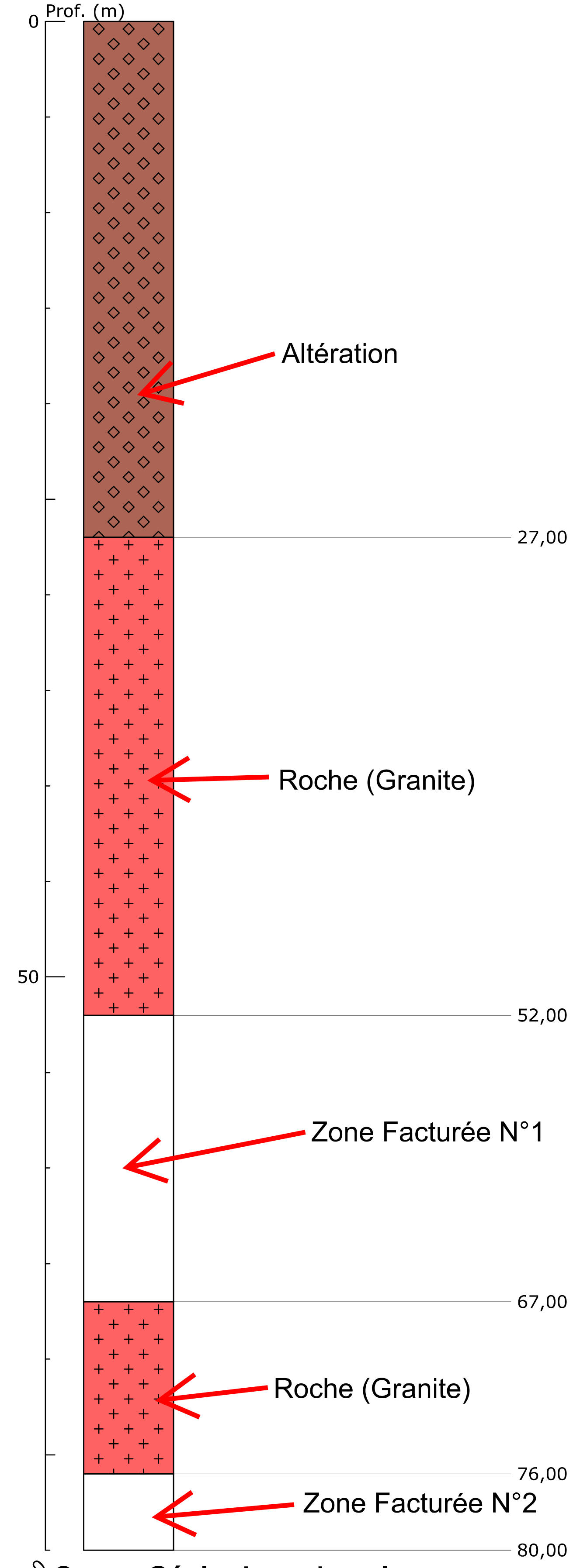
Fin des travaux et photo de famille

ANNEXE

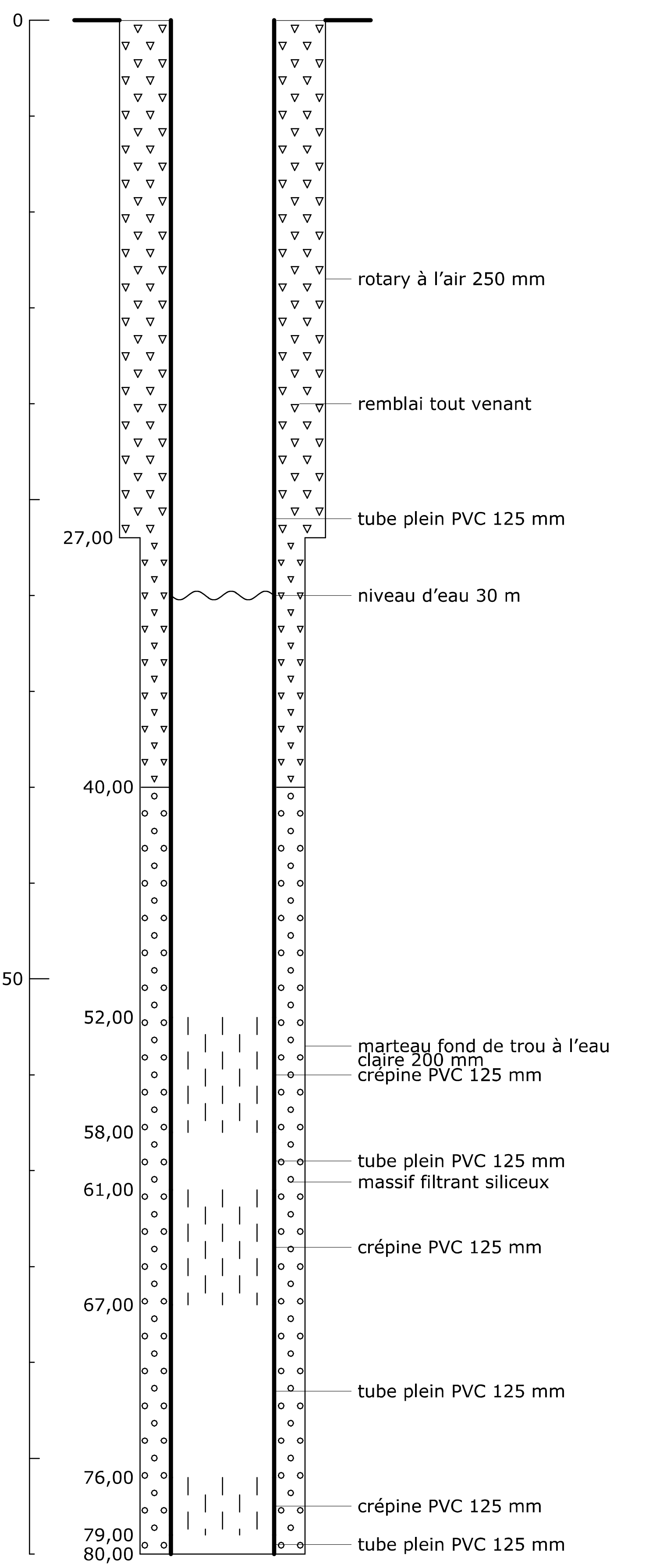
Indice : 1 | Désignation : FORAGE Commune : BANGANGTE (BANEKANE) ( )

Date fin : 25/07/2019 | Lieu-dit : ENTREE UNIVERSITE DES MONTAGNES

Localisation ( ) X : km Y : km Z : m (coupe : m)	Nature : FORAGE Piézométrie indicative (25/07/2019) Utilisation : Profondeur d'eau : 30 m	Débit spécifique : m³/h/m Transmissivité : m²/s Perméabilité : m/s



Coupe Géologique du sol



Plan du tubage

Annex D

Pumping test report

GEWW

Green Energy
Water Well

REPUBLIQUE DU CAMEROUN
Paix– Travail – Patrie

REPUBLIC OF CAMEROON
Peace –Work – Fatherland

RAPPORT DES ESSAIS DE DEBIT

PROJET DE REALISATION D'UN FORAGE D'EAU EQUIPE D'UNE POMPE SOLAIRE DANS LA LOCALITE DE BANEKANE (ENTREE UNIVERSITE DES MONTAGNES), COMMUNE DE BAGANGTE, DEPARTEMENT DU NDE REGION DE L'OUEST

FINANCEMENT PAR : L'ONG PROVALORES

Dossier présenté par:

CIS BTP SARL

Tél : 655 142 942 / 652 448 121

série hydraulique villageoise
COMITE INTERAFRICAIN D'ETUDES HYDRAULIQUES
C.I.E.H

Juillet 2019

SOMMAIRE

PREAMBULE

Les essais de débit simplifié constituent une étape très importante et même indispensable à l'installation de la pompe dans un forage car ils permettent de prévoir les fluctuations de la nappe pendant toutes les saisons. Ce qui permet non seulement d'avoir le débit maximum du forage, mais aussi de déterminer la profondeur d'installation de la pompe sans risque de la dénoyer pendant les périodes de fort étiage.

Dans le cadre de l'exécution des forages dans le département du **NDE**, financé par le ***L'ONG PROVALORES*** et effectuer par CIS BTP SARL dans la localité de **BANEKANE (ENTREE UNIVERSITE DES MONTAGNES)** nous avons procédé, à des essais de débit simplifiés suivant le protocole du **Comité Interafricain d'Etudes Hydrauliques (C.I.E.H)** sous la supervision **des représentants de la population et du Directeur de l'entreprise** qui préconise un pompage sans arrêt pendant une période de quatre heures à des débit bien définis suivi d'une remontée pendant une heure.

Le présent rapport retrace les grandes lignes de ces essais de débit simplifiés, effectués dans ce département et particulièrement dans le cas de ce projet, partant du choix du nombre de paliers à effectuer jusqu'aux analyses et interprétations des résultats en passant par la prise minutieuse des mesures.

I- DEROULEMENT DES ESSAIS DE DEBIT SIMPLIFIES

De manière globale, les essais de débit ont duré 05h00 minutes dont 4h00 de pompage et 1h de remontée**.**

I-1 CHOIX DU NOMBRE DE PALIERS ET DE LEURS DUREES RESPECTIVES

En s'appuyant sur le débit que nous avons obtenu à la fin de la foration et au développement, qui est supérieur à 2 m^3/h, nous avons opté pour un pompage en deux paliers :

Q1 = 1 m^3/h ;

Q2 = 2 m^3/h ;

Q3 = 3 m^3/h.

I-2 MESURE DU NIVEAU STATIQUE ET DE LA PROFONDEUR TOTALE

Avant l'installation de la pompe électrique dans le forage, nous avons mesuré le niveau statique ainsi que la profondeur totale du forage à l'aide d'une sonde électrique

- Niveau statique de forage est de **42.47 m/sol**
- La profondeur est de **78.61 m/sol**

I-3 INSTALLATION DE LA POMPE ELECTRIQUE

La pompe électrique utilise pour les essais de pompage est de marque ASTRAL (1.5 HP), alimentée par un groupe électrogène de puissance 7 HP. Cette pompe a été connectée à un tuyau penaflex de diamètre 32 à l'extrémité duquel a été connectée une vanne.

I-4 MISE EN MARCHE DE LA POMPE ET REGLAGE DU DEBIT DE DEPART

Une fois la pompe installée, elle a été mise en marche et le débit de départ (premier palier) a été callé à l'aide d'un bac jaugé de 10 l et d'un chronomètre.

I-5 CONTROLE DU DEBIT ET CHANGEMENT DES PALIERS

Pendant toute la durée de pompage, le débit a été contrôlé deux minutes avant chaque mesure du niveau statique à l'aide d'une sonde électrique.

I-6 SUIVI DE LA REMONTEE D'EAU

La fin du pompage, nous avons effectué la remonté d'eau pendant une période d'une heure, à l'aide notre sonde électrique.

Sonde électrique
(Sonde piézométrique)

II- ANALYSE ET INTERPRETATION DES RESULTATS

Cette phase consiste à déterminer les caractéristiques du forage afin de connaitre la profondeur exacte d'installation de la pompe pour éviter qu'il ne soit dénoyé.

II-1 PRESENTATION DES RESULTATS

Le Fiche A ci-dessous présente le récapitulatif des mesures faites sur le terrain.

Fiche A TABLEAU DE MESURE	ESSAI DE DEBIT SIMPLIFIE POUR FORAGES	BANEKANE (ENTREE UNIVERSITE DES MONTAGNES)

1 - CARACTERISTIQUES DU FORAGE

Profondeur forée : m/sol

Profondeur mesurée : m/sol

Profondeur socle sain : _______ m/sol

Profondeur venues d'eau:

* à ____ m _______ m3/h
* à _______ m _______ m3/h
* à _______ m _______ m3/h

Profondeur sommet crépine : ____m/sol

Diamètre crépine : _______ mm

Débit fin forage : m3/h

2 - DEVELOPPEMENT DU FORAGE

NS avant développement : ____ m/sol

Date : ___________

Durée :

* Air lift : _______ h
* Pompe : ______ h

Débit :

* Air lift : ________ m3/h
* Pompe : _______ m3/h

Turbidité eau après :

* 30' : _________
* 1 h : _________
* 2 h : _______

NS après développement : m/sol

3 - DONNEES DE L'ESSAI

Repère : TUBE Nature : PVC

4 - MESURE PENDANT L'ESSAI

Date : 29 Juillet 2019 — **CIS BIP SARL**

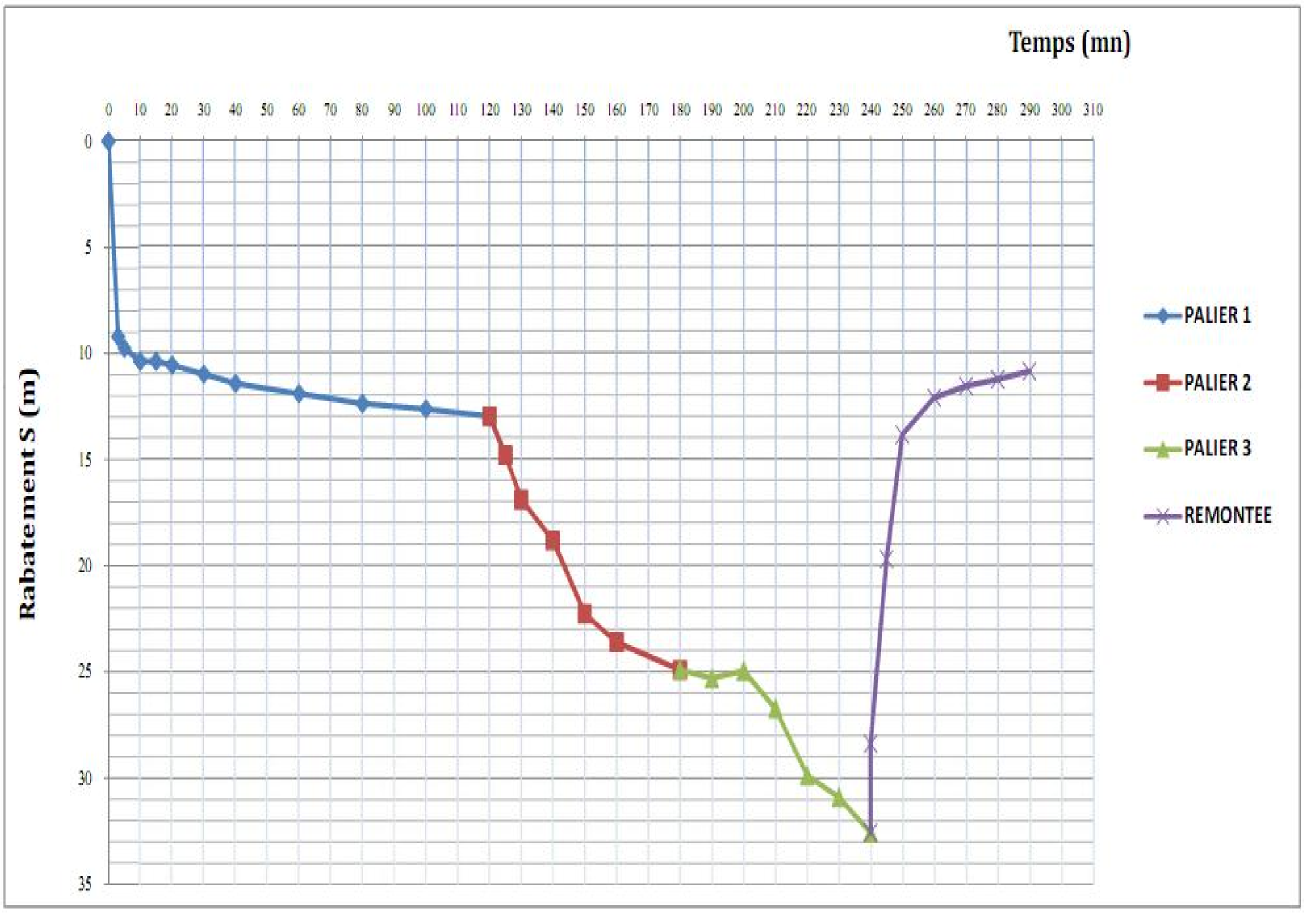
DESCENTE : Pompage de 9h 22mn à 13h22mn

Heure	t (mn)	Niveau eau (m)	Rabatt. S(m)	Débits Q temps (s)	Débits Q m3/h	s/Q (m/m3/h)	Observat°
9H22	0	42,47	0				
	3	51,67	9,2	36	1	9,20	1er palier Eau Trouble
	5	52,22	9,75	36	1	9,75	
	10	52,84	10,37	36	1	10,37	
	15	52,84	10,37	36	1	10,37	
	20	53,02	10,55	36	1	10,55	
	30	53,44	10,97	36	1	10,97	
	40	53,88	11,41	36	1	11,41	
	60	54,36	11,89	36	1	11,89	
	80	54,83	12,36	36	1	12,36	
	100	55,08	12,61	36	1	12,61	
11H22	120	55,42	12,95	36	1	12,95	
	125	57,25	14,78	18	2	7,39	2è palier Eau Claire
	130	59,35	16,88	18	2	8,44	
	140	61,28	18,81	18	2	9,41	
	150	64,73	22,26	18	2	11,13	
	160	66,07	23,6	18	2	11,80	
	180	67,38	24,91	18	2	12,46	
	190	67,77	25,3	12	3	8,43	3è palier Eau Claire
	200	67,42	24,95	12	3	8,32	
	210	69,2	26,73	12	3	8,91	
	220	72,35	29,88	12	3	9,96	

Hauteur/sol : 0,50 m/sol
NS avant essai : 42,47 m/repère
Profondeur avant essai : 78,61 m/rep
Profondeur après essai : 78,61 m/rep
Mesure de débit :
* Tube Pitot : ø _____
* Bac jaugé : 10 litres
pompe :
* type : INTERDAB (1,5 HP)
* Profondeur crépine : m/sol

	230	73,38	30,91	12	3	10,30	
	240	75,04	32,57	12	3	10,86	
REMONTEE							
	t (mn)	Niveau eau (m)	s(m)				Observ.
	245	70,85	28,38				**RAS**
	250	62,16	19,69				
	260	56,29	13,82				
	270	54,55	12,08				
	280	54	11,53				
	290	53,68	11,21				
	300	53,3	10,83				

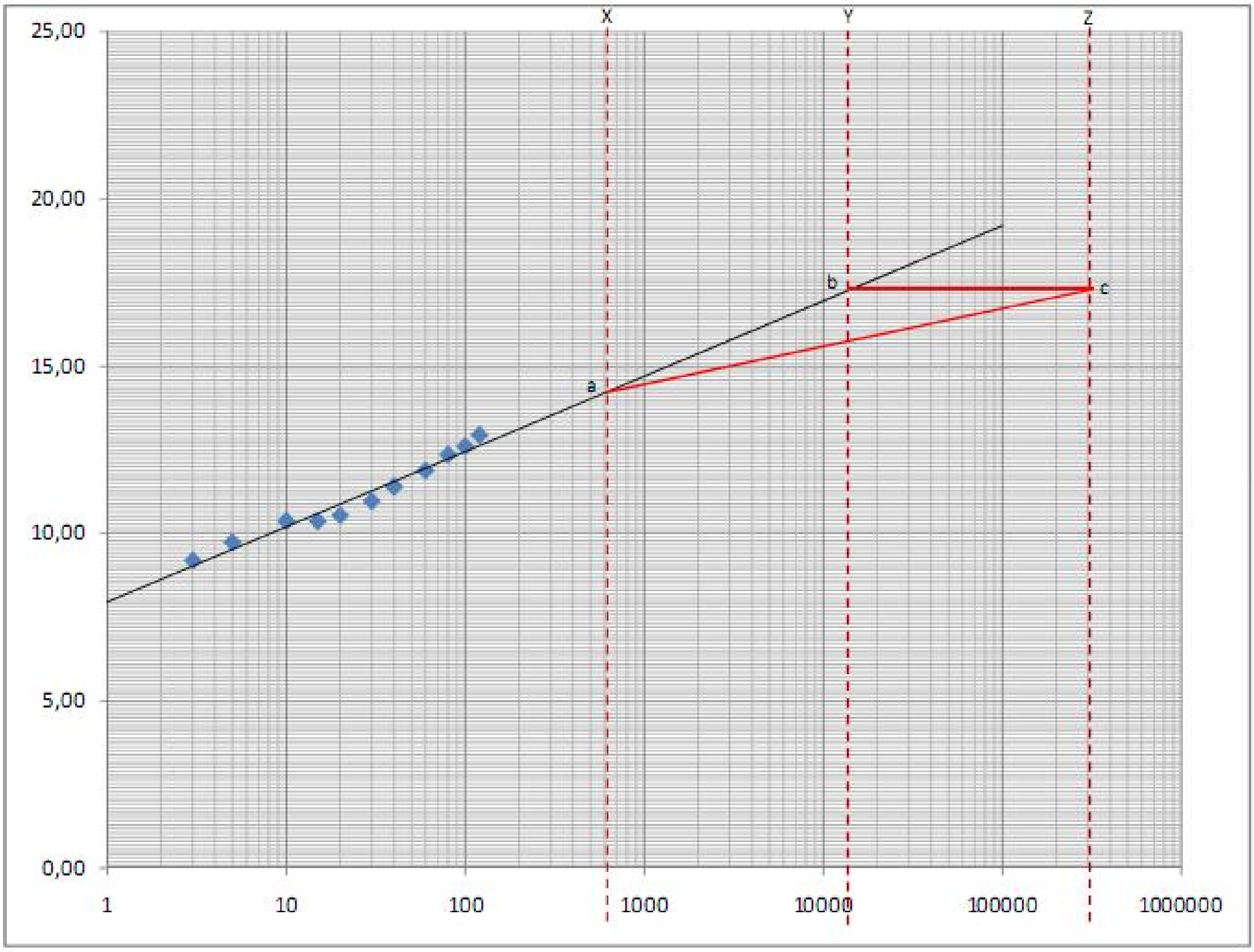
A partir des mesures faites sur le terrain, nous avons établi la courbe d'évolution de la remonté en fonction du temps. La courbe ainsi obtenue nous permet d'avoir une vue du comportement de la nappe du forage soumis à l'épreuve des essais de débit simplifiés.



II-2 CONSTRUCTION DE LA COURBE ESSAI-EXPLOITATION

La présentation du rabattement spécifique (s/Q) du premier palier par rapport au temps a permit d'obtenir la droite semi-logarithmique de **Jacob**. A partir de cette droite, nous avons déterminé le rabattement spécifique après huit mois de pompage 12h/jour (s/Q8m). Aussi, nous avons calculé la pente ***(d)*** de la droite entre 10 mn et 100 mn.

Heure	t (mn)	Niveau eau (m)	Rabatt. S(m)	Débits Q		s/Q (m/m3/h)	Observat°
				temps (s)	m3/h		
8h30	0	42,47	0				
	3	51,67	9,2	36	1	9,20	1er palier Eau Trouble
	5	52,22	9,75	36	1	9,75	
	10	52,84	10,37	36	1	10,37	
	15	52,84	10,37	36	1	10,37	
	20	53,02	10,55	36	1	10,55	
	30	53,44	10,97	36	1	10,97	
	40	53,88	11,41	36	1	11,41	
	60	54,36	11,89	36	1	11,89	
	80	54,83	12,36	36	1	12,36	
	100	55,08	12,61	36	1	12,61	
12H30	120	55,42	12,95	36	1	12,95	



* **<u>Calcul du rabattement spécifique en 8 mois d'exploitation (s/Q8m)</u>**

s/Q8m = 17.5 m/m^3/h et Q = Q1 = 1 m^3/h

s/Q8m = 17.5 m/m^3/h

* **<u>Calcul de la pente (*d*)</u>**

- Pour t=10 mn ⟹ s/Q = 10.37
- Pour t=100 mn ⟹ s/Q = 12.61

D = 12.61 – 10.37 = 2.24 ⟹ **d= 2.24**

II-3 DETERMINATION DU RABATTEMENT MAXIMUM ADMISSIBLE

II-3-1 Détermination du Niveau statique (NS)

Le niveau statique est mesure à l'instant sur le terrain à l'aide de la sonde. Mais pour avoir le niveau réel on le soustraire avec notre repère.

NS = 42.47 – 0.50 = 41.97 m **NS = 41.97 m**

II-3-2 Estimation de la baisse saisonnière de la nappe (aNS)

Elle représente la baisse saisonnière (**aNS**) entre la période d'essai et le mois le plus sec de l'année. Elle s'est faite à l'aide de l'abaque empirique de baisse saisonnière d'une part et le mois le plus sec dans le Département du **NDE**, indiqué par le Délégué Départemental de l'Eau et de l'Energie dudit Département est **Mars.**

- NS= 41.97 m
- Mois d'essai : Juillet
- Mois le plus sec : Mars

⟹ Soit 09 mois d'écart

- Pour NS= 42 m ⟹ ∆NS = 0.8

aNS = 0.8 m

II-3-3 Estimation du niveau statique d'étiage minimale (NSE)

C'est le niveau le plus bas de la saison du forage. Elle est la somme du niveau statique pris sur le terrain et la baisse saisonnière.

NSE = NS + aNS ; NSE = 41.97 + 0.8 = 42.77 m

NSE ù 43 m

II-4 ETABLISSEMENT DE LA CARACTERISTIQUE

II-4-1 Calcule des rabattements corrigés s2* et s3*

Les rabattements corrigés pour 2 heures de pompage aux débits respectifs Q2 et Q3 comme suit :

s2* = s2 + d(0,3 x Q2 – 0,48 x Q1) s2* = 24.91 + 2.24 (0.3 x 2 – 0.48 x 1) = 25.18 m

s3* = s3 + 0,3 x d(Q3 - Q2 - Q1) s3* = 32.57 + 0.3 x 2.24 (3 – 2 – 1) = 32.57 m

s2* = 25.18 m
s3* = 32.57 m

II-4-2 Tracer de la droite caractéristique s/Q = f(Q).

Les points respectifs sont :

* Le point **(e)** : s1/Q1 = 12.95 m/m3/h et Q1= 1 m3/h ;
* Le point **(f)** : s2*/Q2 = 12.59 m/m3/h et Q2 = 2 m3/h ;
* Le point **(g)** : s3*/Q3 = 10.86 m/m3/h et Q3 = 3 m3/h ;
* Le point **(h)** : s8m/Q1 = 17.5 m/m3/h et Q = 1 m3/h

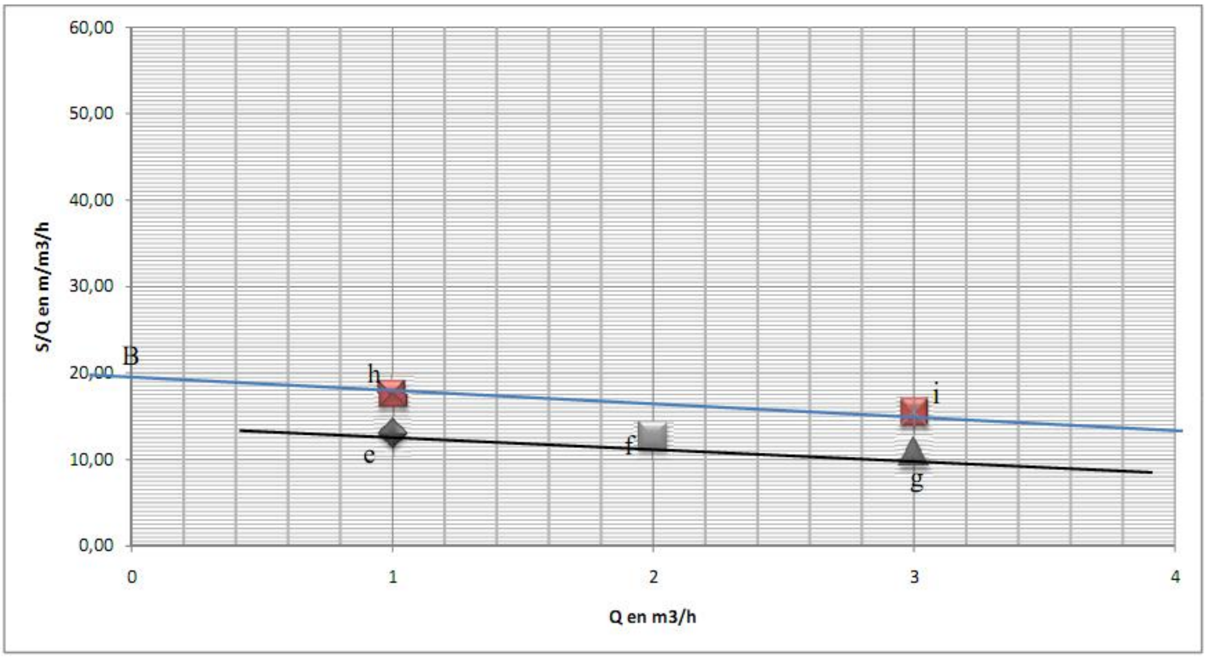
II-4-2-1 Calcule de la pente A et B

A = (s3*/Q3 – s1/Q1) / (Q3 – Q1) ⇨ A= (10.86 – 12.95) / (3 – 1) = -1.05

A = -1.05

Le point **(i):** s/Q = (s8m/Q1 + s3*/Q3 – s1/Q1) = 17.5+ 10.86 – 12.95 = 15.41 m/m3/h et Q3 = 3 m3/h

FICHE B INTERPRETATION		ESSAI DE DEBIT SIMPLIFIE POUR FORAGES				BANEKANE (ENTREE UNIVERSITE)		
1 - Profondeurs/sol		NS/sol	3 - ESSAI DE DEBIT				Date : 29/07/2019	
Forée	/	42.47	Palier	Durée	Débit m3/h	S fin palier	S* corrigé 2h	s*/Q
Tubée	80		1	2h	1	12.95		12.95
Crépine	15		2	1h	2	24.91	44.06	12.59
1ère venue	46	2 - niveau dynamique max	3	1h	3	32.57	56.85	10.86
Toit socle	30	ND MAX : 43 m	Fixé d'après : _________		Etablit par : **CIS BTP SARL**			



LA CARACTERISTIQUE S/Q = F(Q)

2 heures **8 heures**

Le point **B** se lit sur la droite caractéristique sur l'axe des ordonnées

B = 20

II-6 ESTIMATION DU DEBIT MAXIMUM DU FORAGE

Ce débit représente la capacité maximale de production du forage à une période précise de l'année. Il se calcule à partir des Coefficients **A** et **B** calculés ci-dessus, l'équation de la droite caractéristique s/Q = F(Q) à 8 mois est : s/Q = A.Q + B, qui s'écrit aussi : **s = A.Q² + B.Q**.

Cette équation du second degré en Q a pour solution réelle : **Q = ($\sqrt{B^2 + 4.A.s}$- B) / 2.A**

si l'on fixe un rabattement maximum (sMax) voir fiche B ci-dessus, le débit maximum QMax autorisé pour ne pas rabattre au dessous de NDMax s'écrit alors :

Q = ($\sqrt{B^2 + 4.A.s}$Max)- B / 2.A

Pour sMax = 43 m

Q_{Max} = 2.47 m3/h

II-7 POSITIONNEMENT DE LA POMPE D'EXPLOITATION

Il s'agit ici de déterminer la profondeur d'installation de la pompe. En effet, compte tenu de la profondeur du forage qui est 80 m, il convient d'installer la pompe à une profondeur de 70 m. Cela permettre d'éviter au maximum de dénoyer la pompe.

Prof Pompe= 70 m

III- CONCLUSION

Vue le comportement de la nappe pendant le jour de l'essai et la méthode CIEH, les essais ont duré 5 heures de temps donc 4 heures de pompage et 1 heure de remontée, nous pouvons conclure que ce **FORAGE EST POSITIF.**

Annex E

Water quality analysis report

Green Energy
Water Well

MINISTERE DE LA SANTE PUBLIQUE
LABORATOIRE DE BALENG
BP. 228 BAFOUSSAM

LABORATOIRE D'HYGIENE ET DE L'ENVIRONNEMENT
ANALYSE DES EAUX ET DES DENREES ALIMENTAIRES
Agrément N° 2038-01/11/2012 MINSANTE

FORAGE DE BANEKANE(entrée UDM)
Etabli. CIS BIT SARL
MONSIEUR DONPE HERMAN

Tél: 691871794
243 18 54 81
E-mail : laboratoireb@yahoo.com

LABORATOIRE DE BALENG

Laboratoire D'hygiène et de la protection de l'environnement

Autorisation N°2038/01/11/2012

BP 228 Bafoussam. Tel : 237 691871794/343 18 54 81

PARAMETRES PHYSICO-CHIMIQUES

-Origine: Forage **-Localité:** Banekané **-Arrond:** Bangangté

Depart : Ndé– **-Province de:** Ouest-**Demante par:** Monsieur Donpe Herman -

-Entreprise: CIS BIP SARL **-Adresse:** BP -TEL: 655142942

-Prélevée par: le représentant de DEE Baf.

Analysée par_Laboratorien de Baleng.

PARAMETRES PRELIMINAIRES 0RGANOLEPTIQUES.

-Date: 29 /07/2019- **Heure:** 11h30 **H -Temp:**24.9-**PH:** 8,7-**couleur:** limpide -**Odeur:**ss - **DO:**12,9-

conductivi:49.2 µs:Cm3- **Résistivi:** µs/cm3- **Salinité:**0.02 mg/L-**TDS:**31.8ppt -

ANALYSES

PARAMETRES PHYSICO-CHIMIQUES	**Resultats**	**Unités**	**Normes**
PH	**8,7**		6,5-9
Conductivité électrique à 25°c	**49,2**	µS/cm3	10-1100
Résistivité électrique	**20,3**	µS/cm3	10-1100
Salinité:	**0,01**	mg/l	10-100
Turbidité :	**00**	nfu	5-400
Couleur:	**00**	Mg/L	10-500
ALKALINITE			
Alçalinité (TAC)	**135**	mg/mLcaco3	0-500
Carbonates (TA)	**79**	Mg/L caco3	0-500
hydroxydes	**23**	Mg/L caco3	
INDICATEURS DE POLLUTION.			
Nitrites	**0.21**	Mg/L	<0-0,5
Nitrates	**25**	Mg/L	0-20
Ammoniac	**0.00**	Mg /L NH_4	0-1

ANIONS			
Sulfates	**6**	Mg/L	0-200
Sulfites	**0.01**	Mg/L	0-500
Silice	**6.40**	Mg/L	0-150
Phosphates	**68.2**	Mg/L	0-100
Phosphore	**22.5**	Mg/L	0-12
Bore	**0.00**	Mg/L	0-2,5
Chlorures	**3.0**	Mg/L	<250
CATIONS			
Dureté calcique	**7**	Mg/L caco3	0-500
Calcium	**0.00**	Mg/Lca2+	10-100
Dureté totale	**25.4**	Mg/L	0-500
Magnésium	**14**	Mg/L	0-420
Potassium	**0.00**	Mg/L Mo4	0-12
Oxygène dissous	**12.9**	% O_2	0-150
CONTRÔLE DES DESINFECTIONS.			
Chlore libre	**0.36**	Mg/l cl2	0-5
Chlore total	**0.36**	Mg/Lcl2	0-250
Paramètres indésirables			
Aluminium	**0.00**	Mg/Lal	0-0,5
Fer soluble	**0.00**	Mg/Lfer	0-1,0
Fer Total	**0.00**	Mg/l fer	0-5,0
Manganèse	**0.000**	Mg/L	0-0,3
Zinc	**0.00**	Mg/Lzg	0-4,0
PARAMETRES TOXIQUES			
CHROME	**0.04**	Mg/Lcr	0-1.0
Arsenic	**0.00**	Mg/Lar	
Cuivre Libre	**0.00**	Mg/L	0-0,5
Cuivre Total	**0.00**	Mg/L	0-05
Cyanure	**0.00**	Mg/L	0-200
Nikel	**0.15**	Mg/L	0,02
Brome Total	**0.78**	Mg/L	0-10
Brome libre	**0.01**	MG :l	0-10
Etain	**0.00**	Mg/L	10-500

Conclusion : **Eau de qualité CHIMIQUEMENT SATISFAISANTE, EAU DOUCE PAUVRE EN SELS MINERAUX.CONTROLE A ENVISGER UNE FOIS PAR AN.**

NB : Ces résultats ne concernent que cet échantillon examiné ce jour : 31/07/2019

Laboratoire d'Analyses des Eaux et des denrées Alimentaire BP 228 Bafoussam,

LABORATOIRE DE BALENG
ANALYSES DES EAUX ET DES
DENRE'ES ALIMENTAIRES
B.P. 228 BAFOUSSAM
TEL: 233 44 35 19 / 233 18 54 ..

LABORATOIRE DE BALENG

LABORATOIRE D'HYGIENE ET DE LA PROTECTION DE L'ENVIRONNEMENT

(ANALYSES DES EAUX ET DES DENREES ALIMENTAIRES)

Autorisation n°2038 /01/11/2012 du Minsanté

BP 228 Bafoussam

Analyses Bactériologiques des eaux (norme ISO)

Origine : Forage - Localité : Banekané – Commune de :Bangangté

Date :29/07/2019

Prélevée par : le représentant du DEE Bafoussam

Analysée par : le laboratoire » de Baleng.

ANALYSES

Dénominations	Résultats	Normes
Eschérichia Coli /250ml	Absence	Absence
Staphylocoque/250ml	Absence	<20ufc /mL
Salmonellaes/250ml	Absence	Absence
Champignon/250ml	Absence	Absence
Coliformes fécaux /250ml	Absence	<20ufc/ml
Moisissures spores /250ml	Absence	Absence
Pseudomonas Aérugenosaes /250ml	Absence	Absence
Enterobacters/250ml	Absence	Absence
Streptocoques fécaux/250ml/	Absence	<20ufc/ml

Culture faite sur milieu de sartorius.

Conclusion : Eau de qualité SATISFAISANTE SUR LE PLAN MICROBIEN.CONTROLE ET DESINFECTION DEUX FOIS PAR AN.

NB : Ces résultats ne concernent que cet échantillon analysé ce jour : 31/07/2019

Laboratoire d'hygiène et de la protection de l'environnement, BP 228 Bafoussam

Tel : 691871794//00237 343185481

LABORATOIRE DE BALENG
ANALYSES DES EAUX ET DES
DENRE'ES ALIMENTAIRES
B.P. 228 BAFOUSSAM
TEL: 233 44 35 19 / 233 18 54 81

Annex F

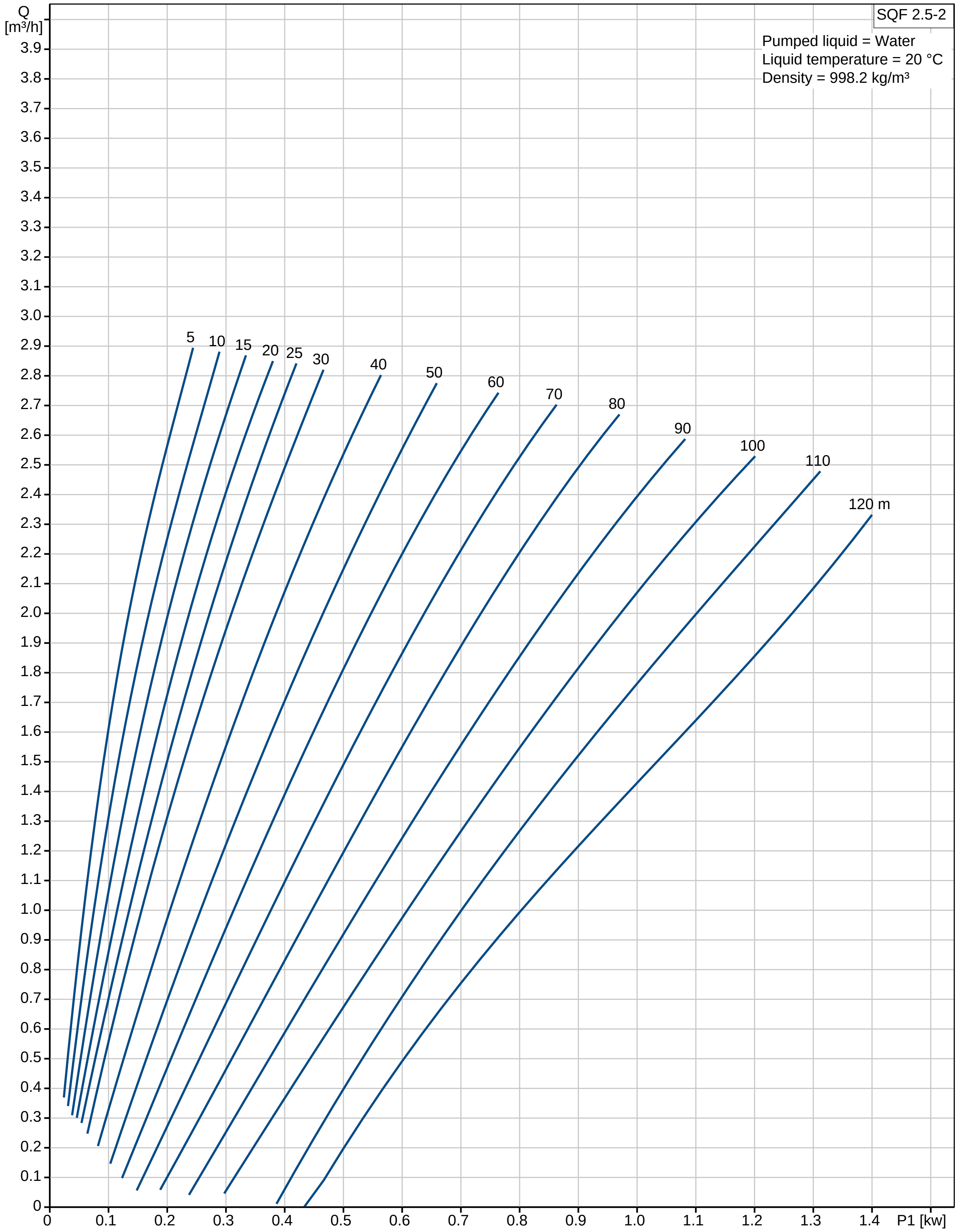
Technical data sheets

GEWW

Green Energy
Water Well

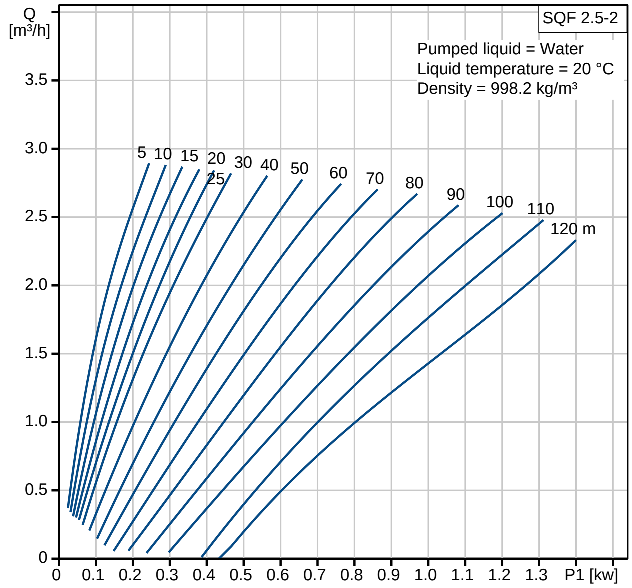
Company name:	-
Created by:	-
Phone:	-
Fax:	-
Date:	-

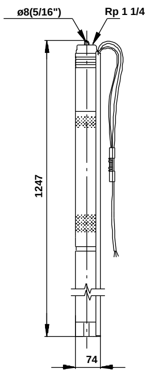
95027330 SQF 2.5-2 50 Hz

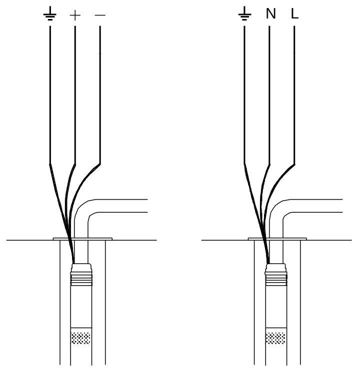


Company name:	-
Created by:	-
Phone:	-
Fax:	-
Date:	-

Description	Value
General information:	
Product name:	SQF 2.5-2
Position	
Product No:	95027330
EAN number:	5700834791741
Price:	On request
Technical:	
Approvals on motor nameplate:	CE,CTICK,TR_MARK
Pump No:	95027414
Stages:	2
Valve:	pump with built-in non-return valve
Materials:	
Pump:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Impeller:	DIN W.-Nr. 1.4301
Rotor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Stator:	Stainless steel / EPDM
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Maximum ambient pressure:	15 bar
Pump outlet:	Rp 1 1/4
Minimum borehole diameter:	76 mm
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Liquid temp:	20 °C
Density:	998.2 kg/m³
Kinematic viscosity:	1 mm2/s
Electrical data:	
Motor type:	MSF3
Power input - P1:	1.4 kW
Rated voltage ac:	1 x 90-240 V
Rated voltage dc:	30-300 V
Start. method:	direct-on-line
Rated current:	8.4 A
Power factor:	1,0
Rated speed:	500-3600 rpm
Enclosure class (IEC 34-5)::	IP68
Insulation class (IEC 85):	F
Motor protec:	Y
Thermal protec:	internal
Length of cable:	2 m
Motor No:	96275336
Others:	
Minimum efficiency index, MEI ≥:	-.--
Net weight:	8.2 kg
Gross weight:	10 kg
Shipping volume:	0.024 m³
Sales region:	Europe/South America/Japan

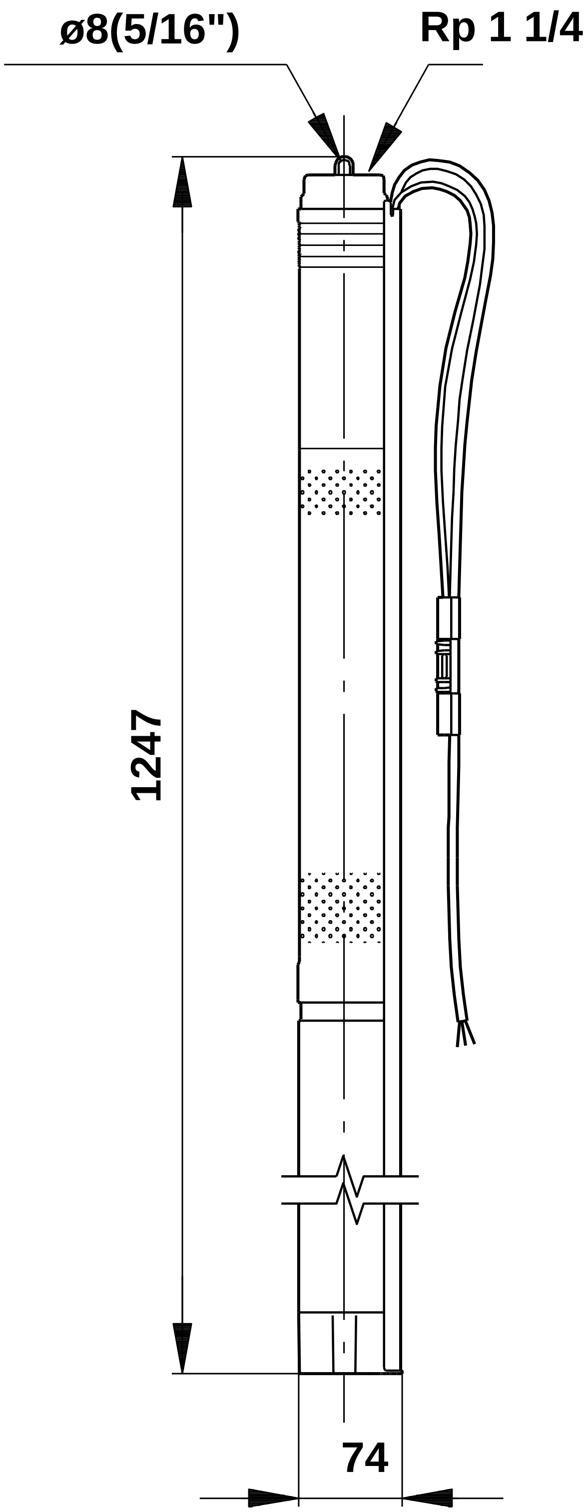






Company name:	-
Created by:	-
Phone:	-
Fax:	-
Date:	-

95027330 SQF 2.5-2 50 Hz

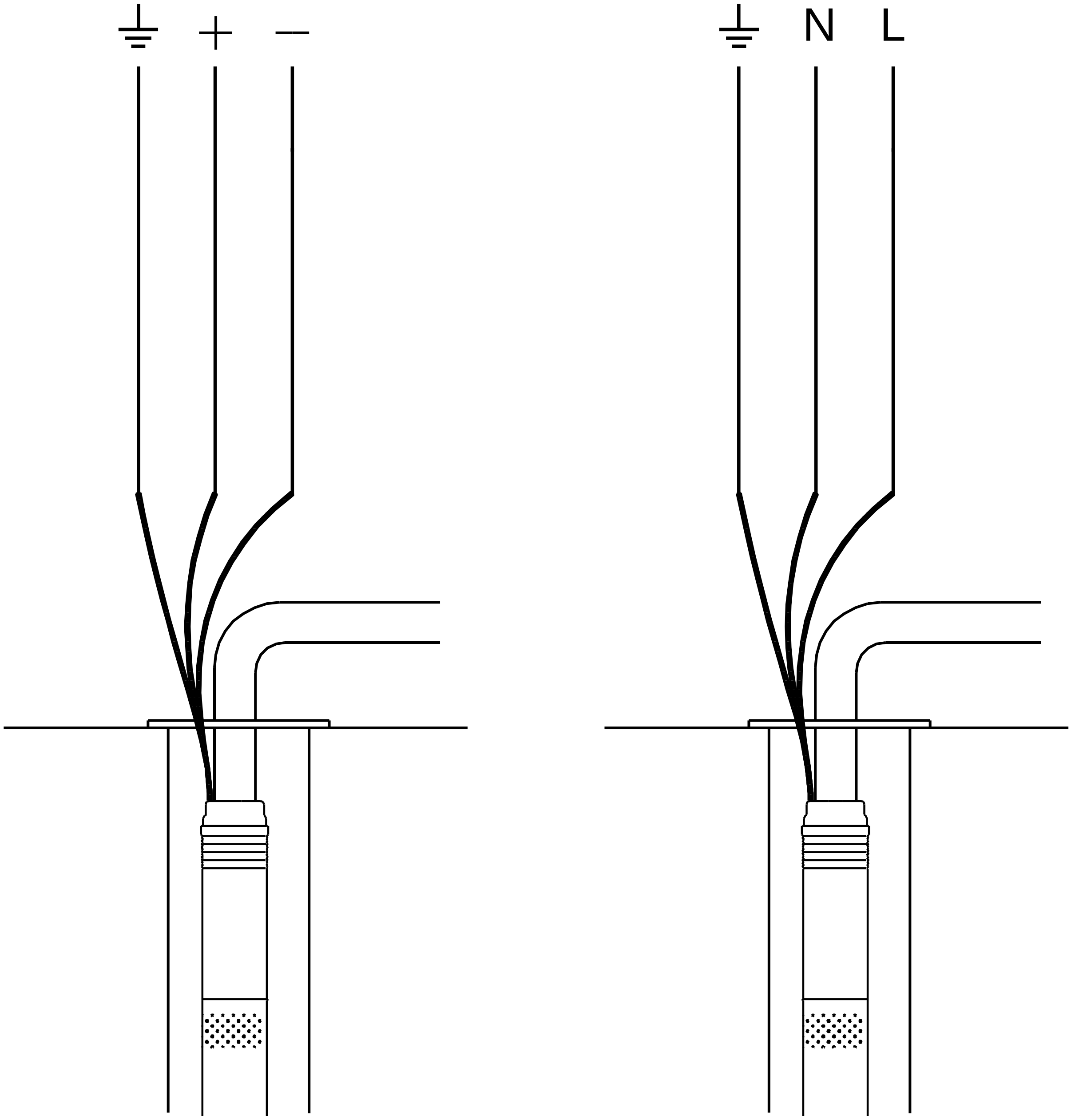


Note! All units are in [mm] unless others are stated.
Disclaimer: This simplified dimensional drawing does not show all details.

GRUNDFOS

Company name: -
Created by: -
Phone: -
Fax: -
Date: -

95027330 SQF 2.5-2 50 Hz



Note! All units are in [mm] unless others are stated.

1.3 Cajas de control y de conexiones

1.3.1 Unidad de control SQFlex CU 200

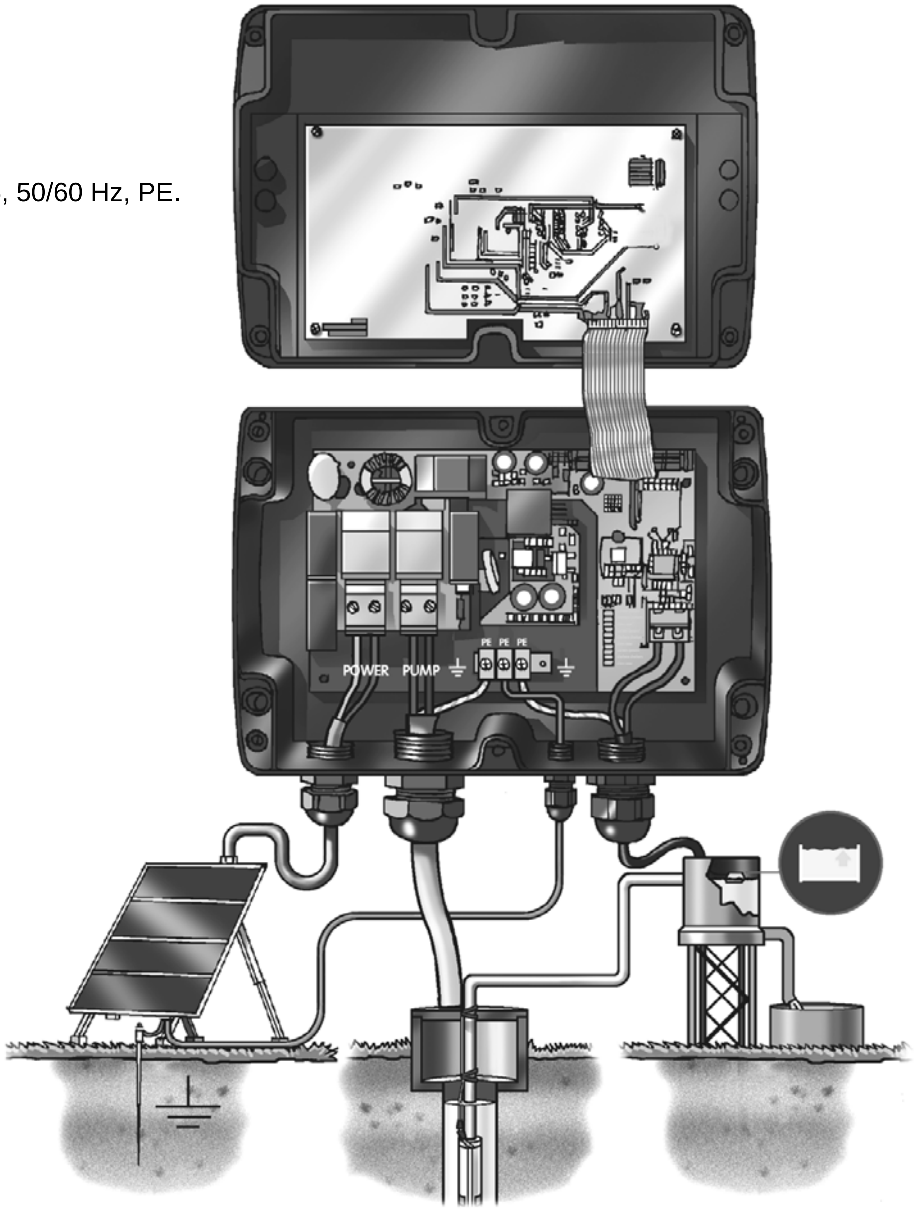
La unidad de control SQFlex CU 200 permite:

- monitorización del sistema basado en las señales de los sensores
- control del sistema basado en las señales de los sensores
- monitorización del funcionamiento de la bomba e indicación de alarmas.

Datos técnicos

- 30-300 VDC, PE.
- 1 x 90-240 V –10%/+6%, 50/60 Hz, PE.

Carga máxima: 100 mA.



Cableado interno (y externo) de la unidad de control SQFlex CU 200

Pantalla y luces de indicación del CU 200 SQFlex

La tapa frontal del CU 200 incorpora un botón y varios indicadores:

Botón ON/OFF

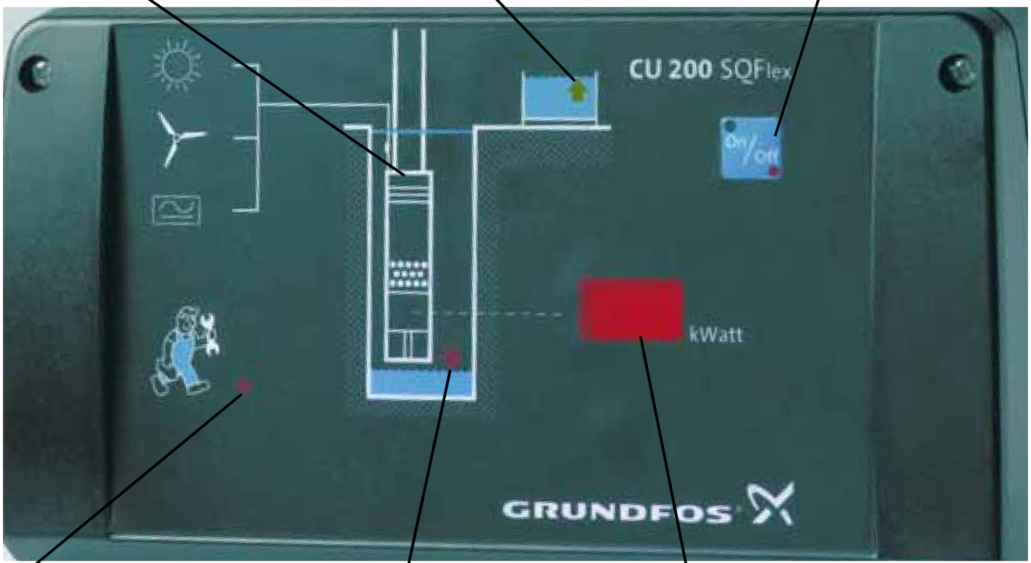
- Luz verde encendida: el sistema ha sido conectado.
- Luz roja encendida: el sistema ha sido desconectado.
- Ambas luces apagadas: el sistema no tiene energía suficiente como para encender la pantalla.
- Luz verde parpadeando: el sistema tiene energía suficiente como para encender la pantalla pero no para arrancar la bomba.

Depósito de agua lleno

La luz amarilla indica que el depósito de agua está lleno.

Funcionamiento de la bomba

Una luz verde indica que la bomba está funcionando a más de 500 min^{-1}.



Indicador de fallo

La luz roja indica fallo.

Funcionamiento en seco

La luz roja indica que falta agua.

Códigos de potencia y fallo

La pantalla indica 0 vatios hasta que la alimentación es suficiente como para hacer funcionar la bomba a 500 min^{-1}; en el arranque, se indica el consumo de la bomba en pasos de 10 vatios, siendo la indicación máxima 1,4 kW.

Cuando el indicador de fallo está encendido, la pantalla muestra los códigos de fallo, véase Corrección de fallos por medio de la CU 200 en la pág. 8.

F1 = sobrevoltaje

F2 = sobretemperatura

F3 = no hay contacto con la bomba

F4 = sobrecargo

Corrección de fallos por medio de la CU 200

Indicación/Fallo	Posible causa	Solución
1. No hay luz en la tapa frontal. La bomba no suministra agua.	No hay tensión de alimentación.	• Restablecer la alimentación.
	El conector del cable plano está mal colocado o el cable está estropeado.	• Corregir la posición del cable o reemplazarlo.
	No está montado el cable plano.	• Colocar el cable plano.
2. No hay luz en la tapa frontal y la bomba no suministra agua. Los LEDs del interior de la unidad CU 200 indican que hay alimentación interna de 5 V, 10 V y 24 V, y el LED "INDICADOR DE CONTROL" no parpadea.	La unidad CU 200 está estropeada.	• Sustituir la unidad CU 200.
3. La bomba no arranca. La luz verde en el botón ON/OFF está encendida. No hay indicación de fallo.	La unidad CU 200 o la bomba está estropeada.	• Compruebe que el LED "INDICADOR DE CONTROL" esté parpadeando. Si no es así, sustituya la CU 200. • Compruebe que hay suficiente tensión en los terminales de la BOMBA. Si no hubiese tensión, sustituya la CU 200. Si se detecta tensión en la bomba, proceda de la siguiente manera: • Desconecte la alimentación de tensión del equipo y espere durante un minuto. • Vuelva a conectar la alimentación y observe lo que sucede: Si el indicador verde del botón ON/OFF está encendido y la bomba sigue sin arrancar, la bomba o el cable de la bomba están estropeados. • Repare o sustituya la bomba o el cable.
4. La luz verde en el botón ON/OFF está encendida.	La bomba se ha detenido.	• Pulse el botón ON/OFF en la unidad CU 200 para arrancar la bomba.
5. La unidad CU 200 indica "F3 = no hay contacto con la bomba".	La CU 200 está estropeada.	• Compruebe - la conexión en la CU 200 - el cable de la bomba - la tapa posterior con enchufe de la bomba.
	El cable de la bomba o las conexiones están estropeadas.	
	La bomba está estropeada.	• Repare o sustituya la bomba.
6. La unidad CU 200 indica "F1 = sobrevoltaje".	La tensión de alimentación sobrepasa el máximo permitido.	• Desconecte los módulos solares para permitir que descienda la tensión. • Reconfigure los módulos y conéctelos. Si se utiliza una fuente de alimentación diferente, compruebe que la tensión está dentro de los límites recomendados. **Nota:** Como la tensión se mide en el motor, tenga en cuenta la caída de tensión en el cable de la bomba.

Indicación/Fallo	Posible causa	Solución
7. La unidad CU 200 indica "F2 = sobretemperatura".	Temperatura del agua demasiado elevada.	• Asegúrese de que la temperatura del agua esté por debajo del nivel máximo permitido.
	Incrustaciones en el motor.	• Retire las incrustaciones del motor.
	La bomba está estropeada.	• Repare o sustituya la bomba.
8. La unidad CU 200 indic "F4 = sobrecarga".	Tensión de entrada demasiado baja.	• Aumente la tensión de alimentación a 30 VDC o más.
	La bomba está estropeada.	• Repare o sustituya la bomba.
	Sólo bombas helicoidales. El líquido de bombeo está contaminado con aceite o sustancias similares.	• Limpie el líquido y sustituya la bomba.
	Insuficiente o falta de líquido en el motor.	• Compruebe el nivel del líquido y rellene si es preciso.
9. El indicador verde del botón ON/OFF parpadea.	Alimentación eléctrica insuficiente.	• Aumente el número de módulos solares, o conecte una fuente de alimentación alternativa, como turbina eólica, baterías o generador.
	La bomba está atascada.	• Limpie la bomba.
10. Luz de marcha encendida en la unidad CU 200, pero se obtiene poca potencia.	El sistema no está puesto a tierra.	• Compruebe que el sistema esté adecuadamente puesto a tierra.
	La bomba está estropeada.	• Repare o sustituya la bomba. Si utiliza una bomba centrífuga: compruebe que la tubería vertical no esté bloqueada.
11. No hay luz en la tapa frontal. La bomba suministra agua.	La CU 200 está estropeada.	• Sustituya la unidad CU 200.
	No está montado el cable plano.	• Colocar el cable plano.
12. La bomba no se detiene cuando el depósito de agua se llena. El indicador de fallo en la CU 200 está apagado.	El interruptor de nivel está sucio o estropeado.	• Limpie o sustituya el interruptor de nivel.
	El cable del interruptor de nivel está estropeado.	• Sustituya el cable.
13. La bomba no se detiene cuando el depósito de agua se llena. El indicador de fallo en la CU 200 está encendido.	La unidad CU 200 está estropeada.	• Sustituya la CU 200.
14. La bomba no arranca cuando el depósito de agua está vacío. El indicador del depósito de agua está encendido.	El interruptor de nivel está estropeado.	• Sustituya el interruptor de nivel.
	El cable del interruptor de nivel está estropeado.	• Sustituya el cable.
	La unidad CU 200 está estropeada.	• Sustituya la unidad CU 200.

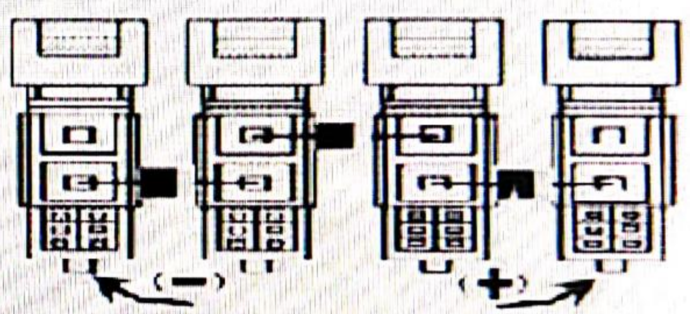
PANASONIC

MODEL : J-M-250W MADE IN JAPAN

Elecrtical Rating at STC(1000W/M², AM1.5 specrtum, cell temperature 25° C)

Peak Power(Pmax)	250W
Production Tolerance of Pmax	3%
Voltage @Pmax(Vmpp)	36V
Current @Pmax(Impp)	6.95 A
Open Circuit Voltag(Voc)	43V
Short Circuit Current(Isc)	7.26A
Dimension of module(mm)	1650*991*50

Maximum Series Fuse	15.0A
Limiting reverse current(Ir)	17.0A



WARNING ELECTRICAL HAZARD

This solar module produces DC electricity when exposed to light

- ALWAYS observe the recommended safety precautions and use the recommended personal protection equipment
- ALL installation and maintenance operations must be carried out by qualified personnel in accordance with local regulations
- BEWARE dangerous DC Voltages and currents may exist when modules are installed
- DO NOT damage or scratch the rear surface of the module
- DO NOT handle or install modules when they are wet or if the backsheet is damaged
- WHEN connecting this solar module to other equipment then refer to the equipment manufacturer's instructions

c UL us LISTED   F M APPROVED   IEC   CE

Annex G

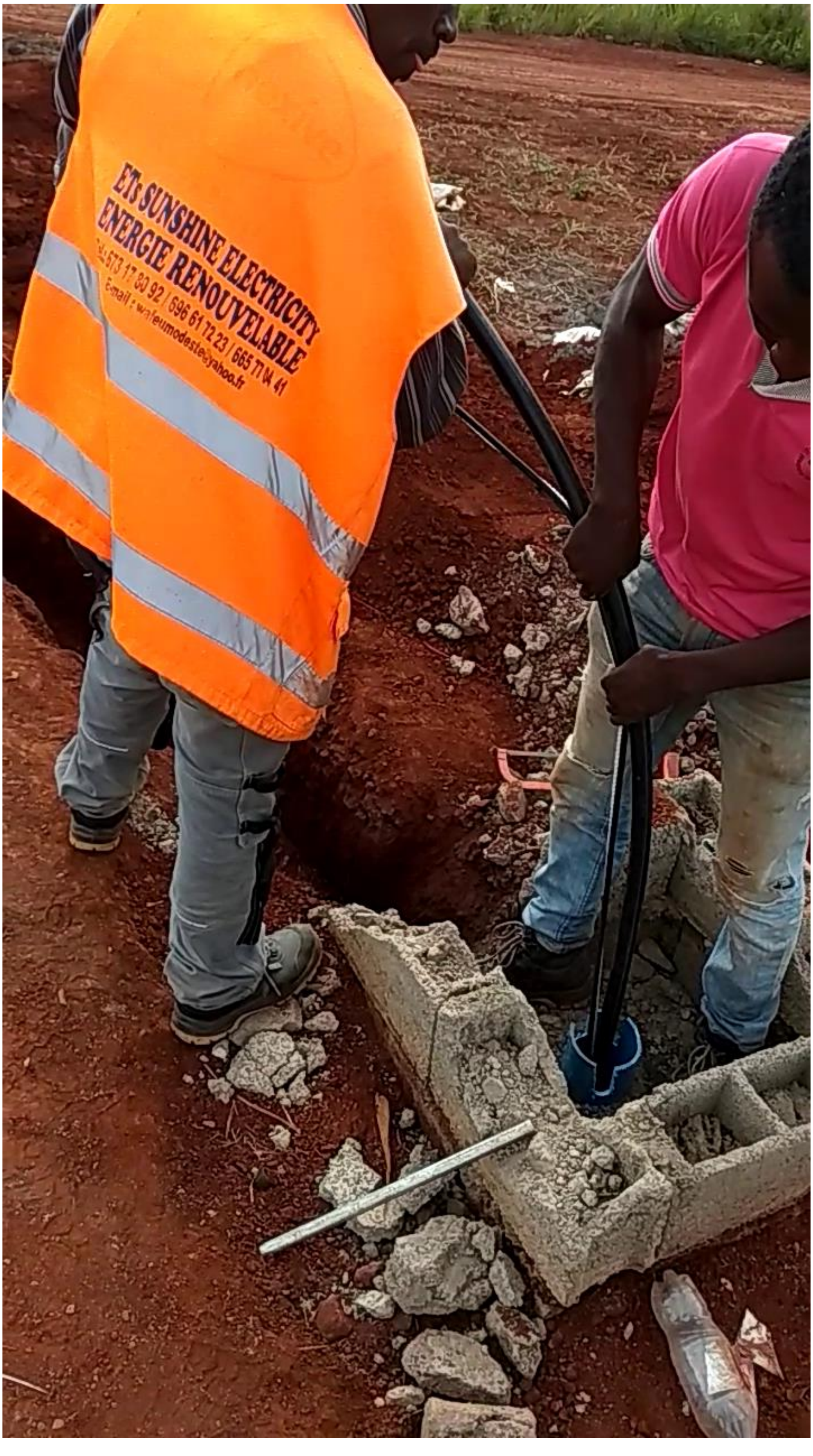
Project photos

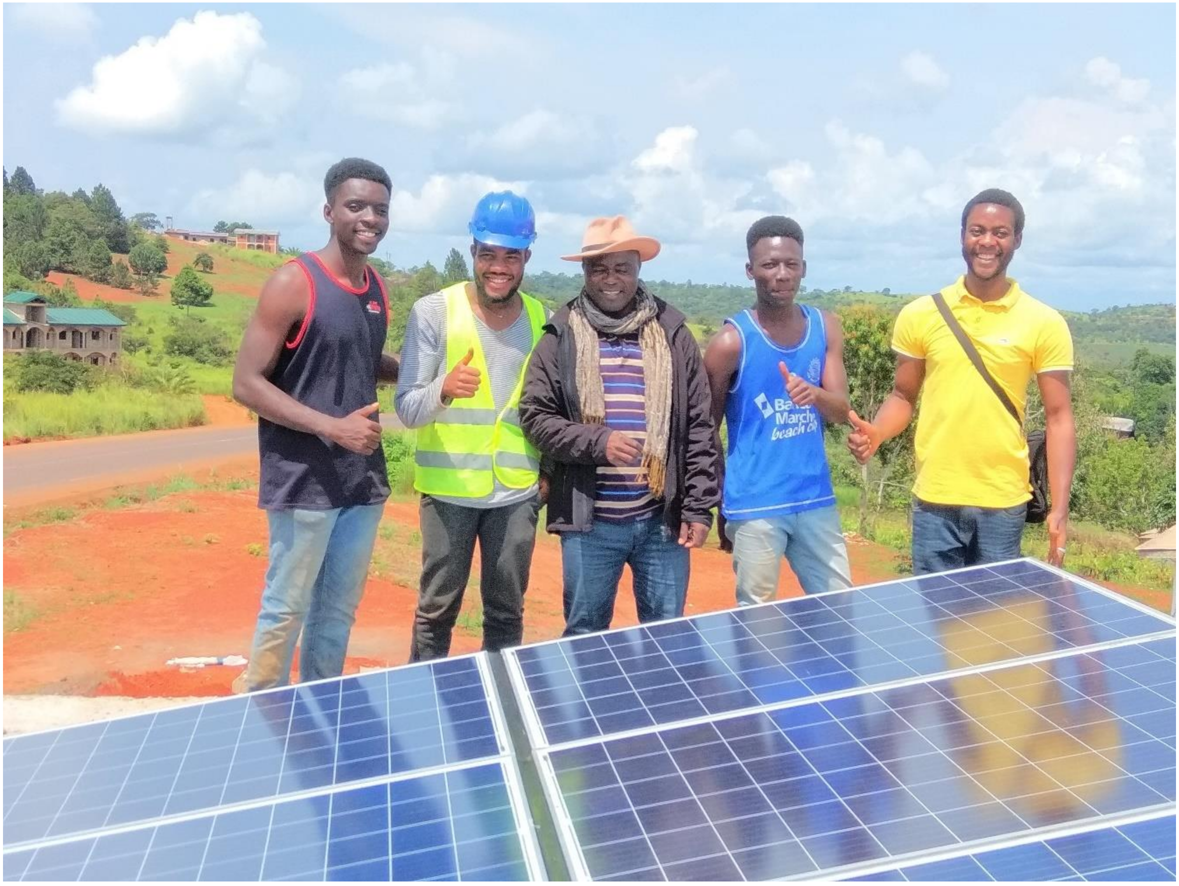
GEWW

Green Energy
Water Well


Ce Grand Africain
Ce Grand Homme
S.E Nelson Mandela


HAZARD
10


ETs SUNSHINE ELECTRICITY
ENERGIE RENOUVELABLE
673 17 80 92 / 696 61 72 23 / 665 77 04 41




ECOLE MATERNELLE
DE BANEKANE


NIKE
ORIGINAL


NIKE


WAVE

Annex H

Land allocation

GEWW

Green Energy
Water Well

Attribution d'un terrain pour la réalisation d'un forage à Bangangté

(BANEKANE)

Monsieur **SAH TCHATON** chauffeur retraité, né vers 1940 à Babou-Bangangté, fils de Tchaton Joseph et de Yankam, domicilié à Yaoundé, BP 1651 Yaoundé; de nationalité camerounaise, propriétaire du titre foncier **869**, délivré le 26 février 1992 par la conservation de la propriété foncière de Bafoussam, inséré au livre foncier du département du Ndé **vol 5 – folio 71 N°869** d'un immeuble rural sis à Bangangté au lieu-dit Banekané a octroyé une parcelle de terrain d'une superficie de **300** m² pour la réalisation d'un forage au même endroit.

SAH TCHATON

Mairie de Bangangté

REPUBLIQUE DU CAMEROUN
REPUBLIC OF CAMEROON
Région de l'Ouest
COMMUNE DE BANGANGTE
Le Maire
Département du Ndé
MINISTERE DE LA DECENTRALISATION ET DU DEVELOPPEMENT LOCAL
MINISTRY OF DECENTRALIZATION AND LOCAL DEVELOPMENT

Dr Kouamouo Jonas

Annex I

Support letters

GEWW

Green Energy
Water Well

REPUBLIQUE DU CAMEROUN
Paix - Travail - Patrie
REGION DE L'OUEST
DEPARTEMENT DU NDE
COMMUNE DE BANGANGTE
B.P. 18 Bangangté- Cameroun
Tel. +237 233 48 41 57 ;
e-mail : nadinenayang@yahoo.fr
site web : www.communedebangangte.net

REPUBLIC OF CAMEROON
Peace-Work-Fatherland
WEST REGION
NDE DIVISION
BANGANGTE COUNCIL
P.O BOX. 18 Bangangté- Cameroon
Phone: +237 233 48 41 57 ;
e-mail : nadinenayang@yahoo.fr
web site : www.communedebangangte.net

N° A3/L/SG/C.BGTE/19

Bangangté, le 30 Janvier 2019

LE MAIRE

A

MONSIEUR ALFREDO VEGA LOPEZ
MAIRE DE TERRASSA (BARCELONE)
ESPAGNE

OBJET : **Avis favorable et soutien au projet de réalisation d'un forage à TCHOUDIM localité dans la Commune de Bangangté.**

Monsieur le Maire,

Dans le cadre des travaux de fin d'étude en Ingénierie de l'Energie à l'Université Polytechnique de Catalogne (UPC), les élèves Ingénieurs **Darcel Aurel YOYA TCHAPTCHET** et **Sergi ORTEGA RUIZ** ont orienté leur projet en faveur du bien-être des populations de TCHOUDIM localité de ma Commune.

A cet effet, avec l'accompagnement de **l'ONG Provolones** ce projet consiste à réaliser un forage à TCHOUDIM pour apporter de l'eau potable au habitants de la communauté. Pour ce forage l'eau sera aspirée et placée dans un réservoir situé en hauteur et fonctionnera avec une pompe à eau qui sera alimentée avec de l'électricité en provenance d'un système de plaques solaires photovoltaïque.

Ce projet innovant est bénéfique pour nos populations s'inscrit en droite ligne des politiques de Développement durable et de Valorisation des Energies propres mise en œuvre dans la commune de Bangangté dans le cadre de la Décentralisation et du Développement Local Participatif.

Aussi, ai-je le bonheur de vous faire part de mon avis favorable ainsi que de tout le soutien de la Commune en faveur de ce projet.

Vous en souhaitant bonne réception et en exprimant tout notre souhait de voir ce projet être le socle d'une coopération décentralisée qu'il nous plaira de densifier en le diversifiant, Veuillez agréer, monsieur le Maire, l'expression de mon profond respect ainsi que mes vœux les meilleurs pour cette nouvelle année.

LE MAIRE

RÉPUBLIQUE DU CAMEROUN
Région de l'Ouest
Commune de BANGANGTE
Le 1er Adjoint au Maire
Département du NDE
MINISTÈRE DE L'ADMINISTRATION TERRITORIALE ET DE LA DÉCENTRALISATION

Dr Kouamouo Jonas

Ampliations :
- Préfet/Ndé
- ONG Provalores
- Intéressés
- Chef du village
- Archives/Chrono

TRADUCCIÓ AL CATALÀ

<u>Objecte</u>: **Dictamen favorable i recolzament al projecte de realització d'un pou a TCHOUDIM, en el municipi de Bangangté**.

Sr. Alcalde,

En el marc dels treballs de fi de grau en Enginyeria de l'Energia a la Universitat politècnica de Catalunya (UPC), els estudiants en enginyeria **Darcel Aurel YOYA TCHAPTCHET** i **Sergi ORTEGA RUIZ** han orientat el seu projecte a favor del benestar de la població de TCHOUDIM, localitat del meu municipi.

Així doncs, amb l'acompanyament de l'ONG Provalores, aquest projecte consisteix a realitzar un pou d'aigua a TCHOUDIM per aportar aigua als habitats de la comunitat. Per aquest pou, l'aigua estarà extreta i emmagatzemada en un dipòsit elevat i funcionarà amb una bomba d'aigua que s'alimentarà amb electricitat provinent d'un sistema de plaques solars fotovoltaiques.

Aquest projecte innovador és beneficiós per als nostres habitants i encaixa amb les polítiques de Desenvolupament sostenible i valoració d'energies netes posades en marxa en el municipi de Bangangté en virtut de la Descentralització del Desenvolupament Local Participatiu.

A més a més, tinc l'honor de comunicar-li el meu parer favorable, així que tot el suport del municipi a favor d'aquest projecte.

Atentament i expressant tot el nostre desig de veure aquest projecte ser la base d'una cooperació descentralitzada que ens agradarà densificar diversificant-lo. Accepti senyor Alcalde, l'expressió del meu profund respecte i us desitjo el millor per aquest any nou.

REPUBLIQUE DU CAMEROUN
PAIX – TRAVAIL – PATRIE
REGION DE L'OUEST
DEPARTEMENT DU NDE
ARRONDISSEMENT DE BANGANGTE

REPUBLIC OF CAMEROON
PEACE – WORK – FATHERLAND
WEST REGION
NDE SUBDIVISION
BANGANGTE SUBDIVISION

Le Chef de quartier NZULKO (Tchoudim)
Aux
Mairies Espagnoles
s/c
Voie hiérarchique

NOUNDOU PIERRE
CHEF DE QUARTIER NZUITKO

Objet : Lettre de soutien et de motivation

J'ai l'honneur de bien vouloir transmettre ci-joint à votre haute autorité et avec avis très favorable notre soutien et motivation pour l'installation du **forage** dans notre village et ses environs par **les Mairies Espagnoles** dans la localité de Tchoudim et ses enivrions (Banekane) Arrondissement de Bangangté, Département du Ndé, Région de l'Ouest Cameroun.

Après des enquêtes menées auprès des populations la venue de ce forage est la préoccupation majeure des habitants (les maladies hydriques et parasitaires). Par conséquent, le village s'engage de garantir la paix et le bon fonctionnement de ce forage.

***Fait à* NZULKO** 21/01/2019

Le Chef de quartier

NOUNDOU PIERRE
CHEF DE QUARTIER NZUITKO

REPUBLIQUE DU CAMEROUN
PAIX – TRAVAIL – PATRIE
REGION DE L'OUEST
DEPARTEMENT DU NDE
ARRONDISSEMENT DE BANGANGTE

REPUBLIC OF CAMEROON
PEACE – WORK – FATHERLAND
WEST REGION
NDE SUBDIVISION
BANGANGTE SUBDIVISION

Le Directeur de l'Ecole Catholique de Banekane
Aux
Mairies Espagnoles
s/c
Voie hiérarchique

Objet : Lettre de soutien et de motivation

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Fait à Banekane le 23/01/2019

Le Directeur

Tchakoute Jean - Paul

Université des Montagnes

Le projet GEWW est une initiative assez innovative et riche, déjà que le but est de venir en aide aux habitants des villages souffrant des carences en eaux potables pour les besoins les plus basiques. De surcroit ce projet est un moyen d'impliquer et motiver les jeunes étudiants dans des projets visant à l'amélioration les conditions de vie des populations défavorisées et aussi le développement et la promotion des énergies renouvelables.

En plus cette initiative permettra aussi donner plus de voix et d'espoirs aux femmes et aux jeunes camerounais. Ce projet permettra aux étudiants d'entrer en contactes avec les habitants du village moyennant des petites formations sanitaires pour améliorer les conditions d'hygiène de ceux-ci.

Et c'est aussi un moyen de créer une association des étudiants de l'Université des Montagnes qui collaborera avec une autre association d'étudiants de l'Université polytechnique de Catalogne dans d'autres futurs projets similaires pour partager les connaissances et mieux se préparer académiquement et surtout professionnellement dans ce monde globalisé.

Ceci-dit, moi, comme représentante des étudiants de l'UdM participant dans ce projet, approuvons les buts de ce projet et nous nous portons volontaires pour aider en la mise en œuvre du projet GEWW de l'ONG *Provalores*.

Représentante des étudiants : Yvie Urielle Mbwutcha Mbiafeu,

Licence en Odontostomatologie

Année scolaire actuelle : Deuxième année

Email : yviembwutcha@gmail.com

Signature :